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## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

## NASA PROGRAM APOLLO WORKING PAPER

FLOW CHARACTERISTICS OF THE LUNAR MODULE  
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NASA PROGRAM APOLLO WORKING PAPER

FLOW CHARACTERISTICS OF THE LUNAR MODULE  
WATER MANAGEMENT SYSTEM

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
MANNED SPACECRAFT CENTER  
HOUSTON, TEXAS  
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## CONTENTS

Section	Page
SUMMARY . . . . .	1
INTRODUCTION . . . . .	1
DESCRIPTION . . . . .	2
Test Article . . . . .	2
Test Equipment . . . . .	2
Instrumentation . . . . .	3
Test Procedures . . . . .	3
Data Requirements . . . . .	4
TEST DISCUSSIONS AND RESULTS . . . . .	5
Tests A and B - General . . . . .	5
Tests C and D - General . . . . .	6
Test C . . . . .	6
Test D . . . . .	7
Tests E and F - General . . . . .	7
Test E . . . . .	7
Test F . . . . .	8
CONCLUDING REMARKS . . . . .	8
RECOMMENDATIONS . . . . .	9
APPENDIX A — TEST DATA . . . . .	39
APPENDIX B — METHOD TO DETERMINE QUANTITY OF WATER LEFT IN THE TANKS AT ANY GIVEN PRESSURE . . . . .	61
APPENDIX C — TEST PROCEDURES . . . . .	65

## TABLES

Table		Page
I	TEST CONFIGURATIONS . . . . .	4
II	SUMMARY OF TEST RESULTS . . . . .	10
III	WATERFLOW CONVERSION PERCENT TO POUNDS/MINUTE . . . . .	11
A-I	TEST A — CALIBRATION SWEEPS — DESCENT WATER TANK WITHOUT WATER DISPENSER/FIRE EXTINGUISHER, WITH HOKE VALVE . . . . .	40
A-II	TEST B — CALIBRATION SWEEPS — ASCENT WATER TANK WITHOUT WATER DISPENSER/FIRE EXTINGUISHER, WITH HOKE VALVE . . . . .	43
A-III	TEST C — DESCENT WATER TANK WITH WATER DISPENSER/ FIRE EXTINGUISHER, WITH HOKE VALVE . . . . .	44
A-IV	TEST D — ASCENT WATER TANK WITH WATER DISPENSER/ FIRE EXTINGUISHER, WITHOUT HOKE VALVE . . . . .	50
A-V	TEST E — DESCENT WATER TANK WITH WATER DISPENSER/ FIRE EXTINGUISHER, WITHOUT HOKE VALVE . . . . .	53
A-VI	TEST F — ASCENT WATER TANK WITH WATER DISPENSER/ FIRE EXTINGUISHER, WITHOUT HOKE VALVE . . . . .	58

## FIGURES

Figure	Page
1 Water dispenser/fire extinguisher designed for Lunar Module . . . . .	12
2 The LM Water Management System simulator . . . . .	13
3 Schematic of LM Water Management System simulator . . . . .	14
4 Test A — flow rate versus descent tank pressure . . . .	15
5 Test A — flow rate versus disconnect discharge pressure . . . . .	16
6 Test A -- flow rate versus Hoke valve pressure . . . .	17
7 Test B — flow rate versus ascent tank and line pressures . . . . .	18
8 Test C — flow rate versus descent tank and line pressures . . . . .	19
9 Test C — flow rate versus descent tank-hose discharge differential pressure . . . . .	20
10 Test C — line flow rate versus time . . . . .	21
11 Test C — descent tank water expended versus time . . .	22
12 Test C — descent tank pressure versus time . . . . .	23
13 Test D — flow rate versus ascent tank and line pressure . . . . .	24
14 Test D — flow rate versus ascent tank-hose discharge differential pressure . . . . .	25
15 Test D — line flow rate versus time . . . . .	26
16 Test D — ascent tank water expended versus time . . . .	27
17 Test D — ascent tank pressure versus time . . . . .	28

Figure	Page
18 Test E — flow rate versus descent tank and line pressure . . . . .	29
19 Test E — flow rate versus descent tank-hose discharge differential pressure . . . . .	30
20 Test E — line flow rate versus time . . . . .	31
21 Test E — descent tank water expended versus time . . . . .	32
22 Test E — descent tank pressure versus time . . . . .	33
23 Test F — flow rate versus ascent tank and line pressures . . . . .	34
24 Test F — flow rate versus ascent tank-hose discharge differential pressure . . . . .	35
25 Test F — line flow rate versus time . . . . .	36
26 Test F — ascent tank water expended versus time . . . . .	37
27 Test F — ascent tank pressure versus time . . . . .	38
C-1 The LM Water Management System simulator . . . . .	71
C-2 Schematic diagram of LM Water Management System Simulator . . . . .	72
C-3 Schematic diagram of Water Management System Charging Unit . . . . .	73

## FLOW CHARACTERISTICS OF LUNAR MODULE

### WATER MANAGEMENT SYSTEM

By R. Trabanino

#### SUMMARY

In-house tests were conducted on the lunar module water management system simulator to determine the flow characteristics of the water management system from the tanks through the firefighting/water dispenser interface. The system pressure losses and flow rates were measured along the water delivery lines downstream of the descent and ascent water storage tanks, at various tank pressures, with the water dispenser/fire extinguisher attached to the end of the flex hose assembly. These are the lines confined to the water dispenser and portable life support system. The test program described in this document presents the results of the tests carried out to determine the flow characteristics of the lunar module water management system and provides basic flow data for additional testing of the fire fighting system.

#### INTRODUCTION

At present, Lunar Module 3 (LM-3) and subsequent LM vehicles are equipped with onboard firefighting equipment, accomplished by incorporation of a fire extinguishing water gun. This fire extinguishing gun is a modified version of the basic LM water dispenser and is expected to provide the LM with an effective fire fighting capability. The Whirlpool Corporation, under the supervision of the Crew Systems Division (CSD), redeveloped the water dispenser into a water dispenser/fire extinguisher gun (fig. 1), incorporating in its design a fire nozzle developed by the Structures and Mechanics Division (SMD).

The water dispenser draws its supply of water from the LM water management system (WMS), designed and built by the Grumman Aircraft Engineering Corporation (GAEC). The WMS and a qualification unit of the water dispenser/fire extinguisher comprised the test apparatus (fig. 2).

Since the flow characteristics of the LM WMS had not previously been experimentally established, SMD conducted this test series to record accurately the system water flow under conditions simulating those to be encountered in flight. Pressure losses and flow rates were monitored at points along the delivery lines downstream from the descent and ascent stage water tanks as the tank pressures dropped from their original predetermined charge pressures to the minimum acceptable pressures. The performance criterion was a uniform flow at sufficient pressure at the extinguisher outlet. Since this test program was concerned only with flow characteristics and did not undertake an evaluation of the actual fire fighting effectiveness of the system, further testing is necessary to establish flight qualification of the fire fighting system.

The author wishes to acknowledge the valuable assistance in preparing this report given him by Donald F. Price, Aerospace Technologist of LM Environmental Control System, Crew Systems Division, Manned Spacecraft Center (MSC), and by David R. Westrich, Student Trainee of Structural Test Section, Structures and Mechanics Division, MSC.

#### DESCRIPTION

##### Test Article

The test article consisted of the LM water management system simulator (part no. LDW 430-51230), the flex hose assembly (LDW 430-51236-1), and the water dispenser/fire extinguisher (Whirlpool part no. 14-0131). The simulator was composed of descent stage (D/S) and ascent stage (A/S) tanks identical to those in the flight vehicle, water lines which approximate vehicle lines in length, and a Hoke valve for flow regulation (the function of the Hoke valve is described under the section entitled "Test Procedures"). This valve and some of the line connections have no equivalent on the flight vehicle. Figure 3 shows a schematic of the system.

##### Test Equipment

The test equipment used consisted of the following ground support equipment:

1. Water transfer unit (LSC 430-94119)
2. Water servicing manifold (LSC 430-54340)
3. Water servicing vacuum pump (LSC 430-54320)
4. Water hoses (LSC 430-54379)

The four items mentioned above comprise the unit commonly known as the water charging unit. This unit is the responsibility of GAEC; hence, all water loading of the tanks at MSC was accomplished under GAEC supervision and procedures.

#### Instrumentation

In addition to the ground support equipment outlined above, the following instrumentation was used during the test:

1. Pressure transducer each for descent and ascent tank  
(range: 0 to 75 psia)
2. Descent and ascent tank disconnect pressure transducer  
(range: 0 to 75 psia)
3. Hoke valve differential pressure transducer  
(range: 0 to 50 psia)
4. Water flowmeter (range: 0- to 100-percent flow)
5. Hose discharge pressure transducer (range: 0 to 50 psia)

#### Test Procedures

All tests were conducted in accordance with the development test plan for LM WMS for fire extinguishing purposes, Structures Branch Report no. 68-ES4-2. Test procedures have been excerpted from the test plan and are presented in Appendix C.

Six tests were conducted on the LM WMS simulator; three tests used the descent tank and three the ascent tank. The tests were labeled from A to F, inclusive, and had configurations as shown in table I.

Before each test, reference points were calibrated in accordance with the development test plan for LM WMS, Structures Branch Report no. 68-ES4-2 (Appendix C). During tests A, B, and C the Hoke valve was used to confine the flow to the limits established in the test plan. It was the intent of these tests to utilize the Hoke valve as a device to throttle the flow through the system to compensate for the actual pressure head loss to be encountered during actual flight conditions. For tests D, E, and F the Hoke valve was removed. The explanation for this action is found within the description of each individual test.

TABLE I.- TEST CONFIGURATIONS

Test	Water tank	<u>Water dispenser/ fire extinguisher</u>	Hoke valve
A	D/S	NO	YES
B	A/S	NO	YES
C	D/S	YES	YES
D	A/S	YES	NO
E	D/S	YES	NO
F	A/S	YES	NO

The test plan called for only one test run of each condition, but during the course of the testing it was decided to make one more test run for both descent and ascent water tank (tests E and F) to obtain a higher level of confidence in the flow characteristics.

The removal of the Hoke valve during tests D, E, and F and addition of tests E and F were the only deviations from the test plan.

#### Data Requirements

Data were recorded during all the tests and are tabulated in appendix A. Time intervals between successive readings were recorded as well as total time elapsed from the beginning to end of tests. Figures 4 to 27 include flow characteristics curves plotted from this test data. The following data were plotted for all tests performed:

1. Flow rate versus pressure in the descent tank, ascent tank, disconnect discharge, and hose discharge
2. Flow rate versus differential pressure from tanks to hose discharge
3. Flow rate versus time

Additional graphs were plotted for tests C, D, E, and F and are as follows:

1. Water used and water remaining in the tanks versus time  
(See appendix B for the manner in which data were calculated to plot these graphs.)

2. Tank pressure versus time

#### TEST DISCUSSIONS AND RESULTS

The results of all tests are described in this section and are also presented in summary form in table II.

##### Test A and B - General

Test A configuration was D/S water tank without water dispenser/fire extinguisher, with Hoke valve. Test B configuration was A/S water tank without water dispenser/fire extinguisher, with Hoke valve. The first two tests, tests A and B, were functional in that the primary objective was to check out the system and to familiarize the personnel with the functional characteristics of the simulator. Data were obtained during the first two tests and are presented in appendix A. The initial pressure used during test A was 48.5 psia, and during test B was 49.0 psia. These pressures closely approach the pressure in the tanks of 48.0 psia during the prelaunch phase, but no correction was made to compensate for the pressure differential which would exist in the cabin during spaceflight. Tests A and B did not include the water dispenser/fire extinguisher as part of their configuration; therefore, no back pressure or pressure loss was experienced at the outlet.

After calibration of reference points the tests were conducted as outlined in step 4 of the test procedures (appendix C). That is, flows were consecutively established from 0.5 lb/min (equivalent to 5-percent flow) to a maximum obtainable flow of 8.6 lb/min (equivalent to 92-percent flow). These relations are shown in table III - Water Flow Conversion Table. Decreasing flows were then established from the highest flow (8.6 lb/min obtained in the first run), down to the initial low flow (0.5 lb/min). The above steps were repeated four times, with a decay of the high-flow reading as the pressure decreased. Descent and ascent tank pressures, disconnect discharge pressure, and Hoke valve differential pressure were recorded throughout the five cycles.

Summary for tests A and B: The highest pressures recorded were 48.0 psia for the descent tank and 49.0 psia for the ascent tank; the lowest pressures recorded were 23.9 psia and 15.2 psia, respectively. At the latter pressures the flows were not considered to be adequate and tests A and B were terminated. Elapsed time from beginning of the test to the end was not recorded.

#### Tests C and D - General

For tests C and D the WMS was used in conjunction with the water dispenser/fire extinguisher. The descent and ascent water tanks were pressurized to 58 psia, which is 10 psia higher than initial operating flight pressure. This additional pressure in the tanks was provided to simulate more closely the actual pressure differential between the WMS and the LM cabin during flight with full tanks (approx. 43 psia), when full-water system is approximately 48 psia and the LM cabin pressure during flight is 4.6 to 5.0 psia. Following is a list of the pressure conditions which justify an initial tank pressure of 58 psia:

Operating pressure during flight (full tanks) = approx. 48 psia

Cabin pressure during flight = 4.6 to 5.0 psia

Differential pressure between tanks and cabin = approx. 43 psia

Tank pressure necessary during test = approx. 58 psia

Ambient pressure during test = 14.7 psia

Differential pressure during test = approx. 43 psia

Test C. - Test C configuration was D/S water tank with water dispenser/fire extinguisher, with Hoke valve. The test was conducted with a pressure of 58 psia in the descent tank. The Hoke valve upstream of the flowmeter was used to simulate a pressure drop equivalent to the decrease in pressure in the IM system. The water dispenser in the actual vehicle is located approximately 9.15 feet above the descent tank, resulting in an equivalent pressure drop of 0.7 psia at 1/6g environment. During the test it was discovered that the pressure drop across the fully opened Hoke valve was 1.85 psia, which is higher than the drop calculated to comprise the pressure head loss. Consequently, the data obtained are conservative for the period of time in which the Hoke valve pressure drop was higher than the expected drop. Eventually, as pressure and volume of the water in the tank dropped, the Hoke valve effectively throttled to maintain a drop of 0.7 psia.

Summary for test C: The highest flow rate obtained during test C was 5.05 lb/min. It was noted that the pressure in the tank dropped approximately 30 psia during the first 40 minutes as compared to a drop of approximately 4 to 5 psia during the remaining 90 minutes of the test. At T + 1 hour 6 minutes, when the flow was down to about 1.4 lb/min and the pressure in the tank was 19 psia, the flow readings became erratic. At this time the cone of water was 2 to 3 inches in diameter at approximately 1 foot from the dispenser. (Water from the extinguisher sprayer forms a full cone of water.) The cone of water formed at the beginning of the test was approximately 4 to 5 feet in diameter at a distance of 6 feet from the dispenser.

Test D.- Test D configuration was A/S water tank with water dispenser/fire extinguisher, without Hoke valve. The test was conducted with 58-psia pressure in the ascent tank. The Hoke valve was removed from the system because the tank is located above the water dispenser during ascent from the lunar surface and thereby eliminates the need for compensation since the pressure head does not act against the system.

Summary for test D: The highest flow rate obtained during test D was 5.05 lb/min. During the first 2 minutes of the test, the tank pressure dropped rapidly from 58 psia to 29.8 psia. At T + 6 minutes the pressure in the tank was down to approximately 21.0 psia and the flow was 1.87 lb/min. At this time the cone (or spray) of water cut off the dispenser was only 2 to 3 inches in diameter 1 foot away from the dispenser.

As in test C, at the beginning of the test the cone was approximately 4 to 5 feet in diameter at a distance of 6 feet from the dispenser.

#### Test E and F - General

For tests E and F, the WMS was used in conjunction with the water dispenser/fire extinguisher. As in tests C and D, a tank pressure of 58 psia was used. The Hoke valve was taken out of the system because it was demonstrated during test C that the pressure drop across this valve was higher than anticipated. During tests E and F the readings were timed with more accuracy than during the preceding tests. Results obtained during tests E and F are considered to be as accurate as is possible with practicable operating standards.

Test E.- Test E configuration was D/S water tank with water dispenser/fire extinguisher, without Hoke valve. Test E, as in the previous tests, was conducted with a 58-psia descent tank pressure.

During this test the time interval between each successive set of readings was recorded with more accuracy than in other tests. A mathematical check was made of the time element by comparing the sum of the times elapsed between readings against the total time consumed from the start to the conclusion of the test. A comparison of the duration of test E with that of test C showed a difference between the two runs of only a few seconds.

Summary for test E: The highest flow rate obtained during test E was 5.42 lb/min. At T + 40 minutes the flow was down to 2.5 lb/min and the tank pressure was down to 24.6 psia. During the remaining 44 minutes of the test the pressure dropped to approximately 20 psia. At T + 1 hour 13 minutes the flow became erratic and the pressure had dropped to approximately 19 psia. The test was concluded at approximately T + 1 hour 24 minutes.

As in previous tests, the water cone formed at the beginning of the test was approximately 4 to 5 feet in diameter at a 6-foot distance from the water dispenser. At the end of the test the cone formed was 2 to 3 inches in diameter 1 foot away from the dispenser.

Test F. - Test F configuration was A/S water tank with water dispenser/fire extinguisher, without Hoke valve. Test F was conducted with 58 psia ascent tank pressure. During this test the time lapse between each successive set of readings was recorded with more accuracy than in test D. Flow which was considered adequate lasted for approximately 10 minutes, which is 4 minutes longer than in test D. No reasonable explanation can be found for the apparent time anomaly concerning the duration of test D.

Summary for test F: The highest flow rate recorded during test F was 5.23 lb/min. At T + 10 minutes the flow was down to 1.9 lb/min and the tank pressure was down to 21.0 psia. At this time the cone of water out of the dispenser was approximately 2 to 3 inches in diameter at a 1-foot distance from the dispenser. As in all of the tests, a cone of water 4 to 5 feet in diameter was formed 6 feet away from the dispenser at the beginning of the test.

#### CONCLUDING REMARKS

The results of the various tests presented in this document established the flow rates and pressures to the water dispenser/fire extinguisher during different stages of flight with tank pressures in the range of 58 to 21 psia (43.3 to 6.3 psig). Under actual LM flight conditions (5.0 psia cabin pressure) the water tanks are essentially empty

at about 7 psig. The test results (6.3 psig minimum) verify the capability of the WMS to provide flows at pressures below the minimum expected in flight. However, it should be noted that during the course of this series of tests, no allowance was made for additional uses for this water such as: water required for the crew, for the sublimators, and for portable life support system. Therefore, a thorough investigation of the water profile for each mission, in conjunction with the data presented in this document, would provide the information necessary for determining the amount of water available for fire suppression on-board the LM during lunar missions.

#### RECOMMENDATIONS

Following are recommendations for further study of the LM water management system:

1. Followup tests should be conducted using actual fires within the spacecraft mockup to determine the fire extinguishing capabilities of the system. Special emphasis should be placed on the lower flows and pressures so as to determine minimum capabilities of the system.
2. The LM water management system simulator and associated equipment should be used in conjunction with the LM Mockup or equivalent.

TABLE II.—SUMMARY OF TEST RESULTS

Test	Tank pressure	Hoke valve	Minimum acceptable tank pressure <sup>a</sup> , psia	$\Delta P$ , tank to hose discharge	Water dispenser	Maximum flow, lb/min	Minimum recorded flow, lb/min	Time <sup>b</sup> , min
A calibration	Descent 48 psia	Yes	N/A	N/A	No	8.6	0.5	N/A
B calibration	Ascent 48 psia	Yes	N/A	N/A	No	6.6	0.5	N/A
C	Descent 58 psia	Yes	19	See fig. 9	Yes	5.05	1.40	66
D	Ascent 58 psia	No	21	See fig. 14	Yes	5.05	1.87	6
E	Descent 58 psia	No	19	See fig. 19	Yes	5.42	1.50	73
F	Ascent 58 psia	No	21	See fig. 24	Yes	5.23	1.9	10

<sup>a</sup>This pressure sustains a water cone of 2 to 3 inches in diameter, 1 foot away (original pressure of 58 psia formed 4- to 5-foot diameter cone 6 feet away).

<sup>b</sup>Time elapsed from the beginning of the test until such time as the flow was not considered adequate.

TABLE III.- WATER FLOW CONVERSION

PERCENT TO POUNDS/MINUTE

Percent	lb/min	Percent	lb/min	Percent	lb/min
1	0.09	34	3.18	68	6.35
2	.19	35	3.27	69	6.45
3	.28	36	3.36	70	6.54
4	.37	37	3.46	71	6.63
5	.47	38	3.55	72	6.73
6	.56	39	3.64	73	6.82
7	.65	40	3.74	74	6.91
8	.75	41	3.83	75	7.01
9	.84	42	3.92	76	7.10
10	.93	43	4.02	77	7.19
11	1.03	44	4.11	78	7.29
12	1.12	45	4.20	79	7.38
13	1.21	46	4.30	80	7.47
14	1.31	47	4.39	81	7.57
15	1.40	48	4.48	82	7.66
16	1.49	49	4.58	83	7.75
17	1.59	50	4.67	84	7.85
18	1.68	51	4.76	85	7.94
19	1.78	52	4.85	86	8.03
20	1.87	53	4.95	87	8.13
21	1.96	54	5.05	88	8.22
22	2.06	55	5.14	89	8.31
23	2.15	56	5.23	90	8.41
24	2.24	57	5.33	91	8.50
25	2.34	58	5.42	92	8.60
26	2.43	59	5.51	93	8.69
27	2.52	60	5.61	94	8.78
28	2.62	61	5.70	95	8.88
29	2.71	62	5.79	96	8.97
30	2.80	63	5.89	97	9.06
31	2.90	64	5.98	98	9.16
32	2.99	65	6.07	99	9.25
33	3.08	66	6.17	100	9.34
		67	5.26		

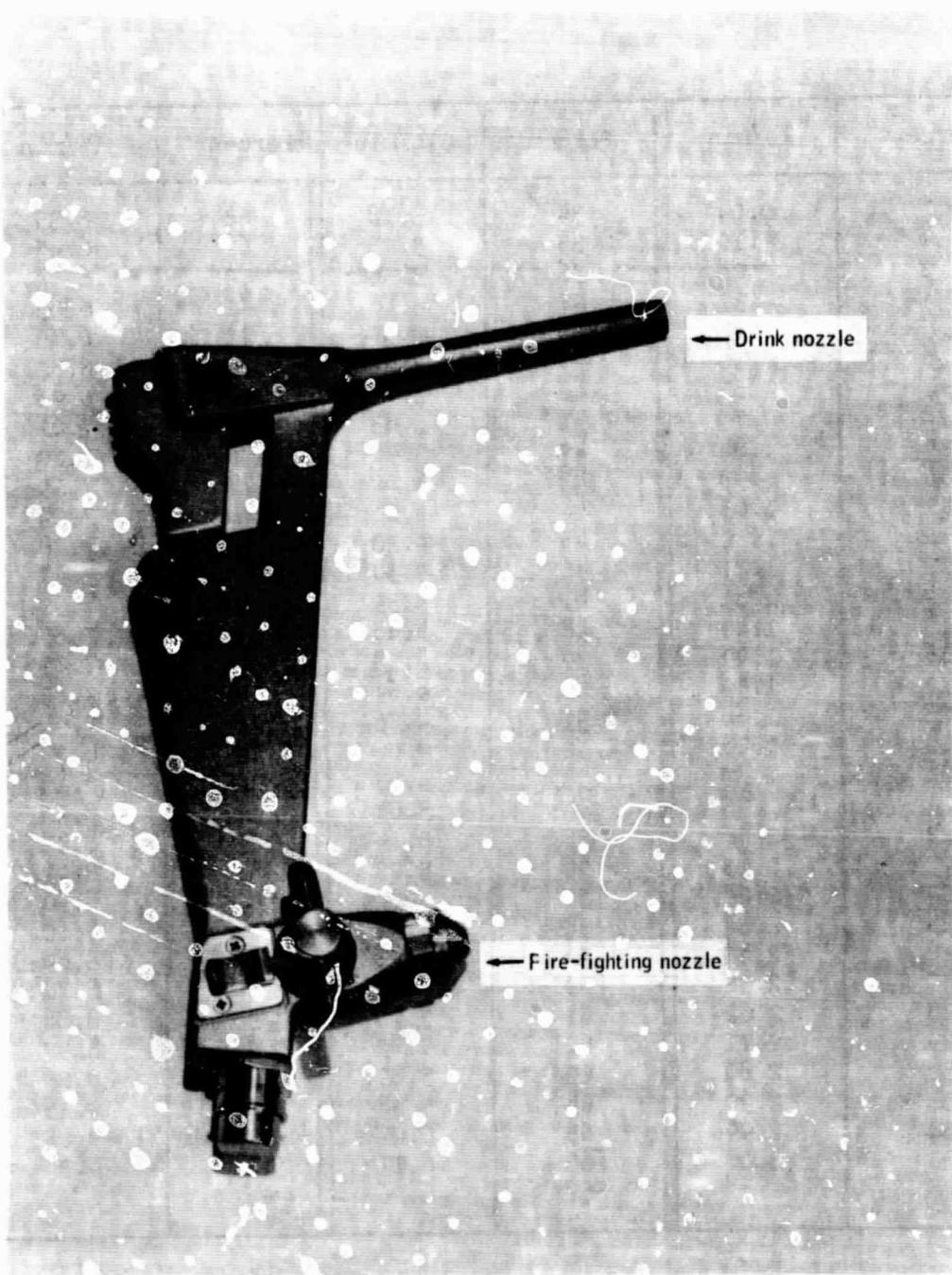


Figure 1.- Water dispenser/fire extinguisher designed for lunar module.

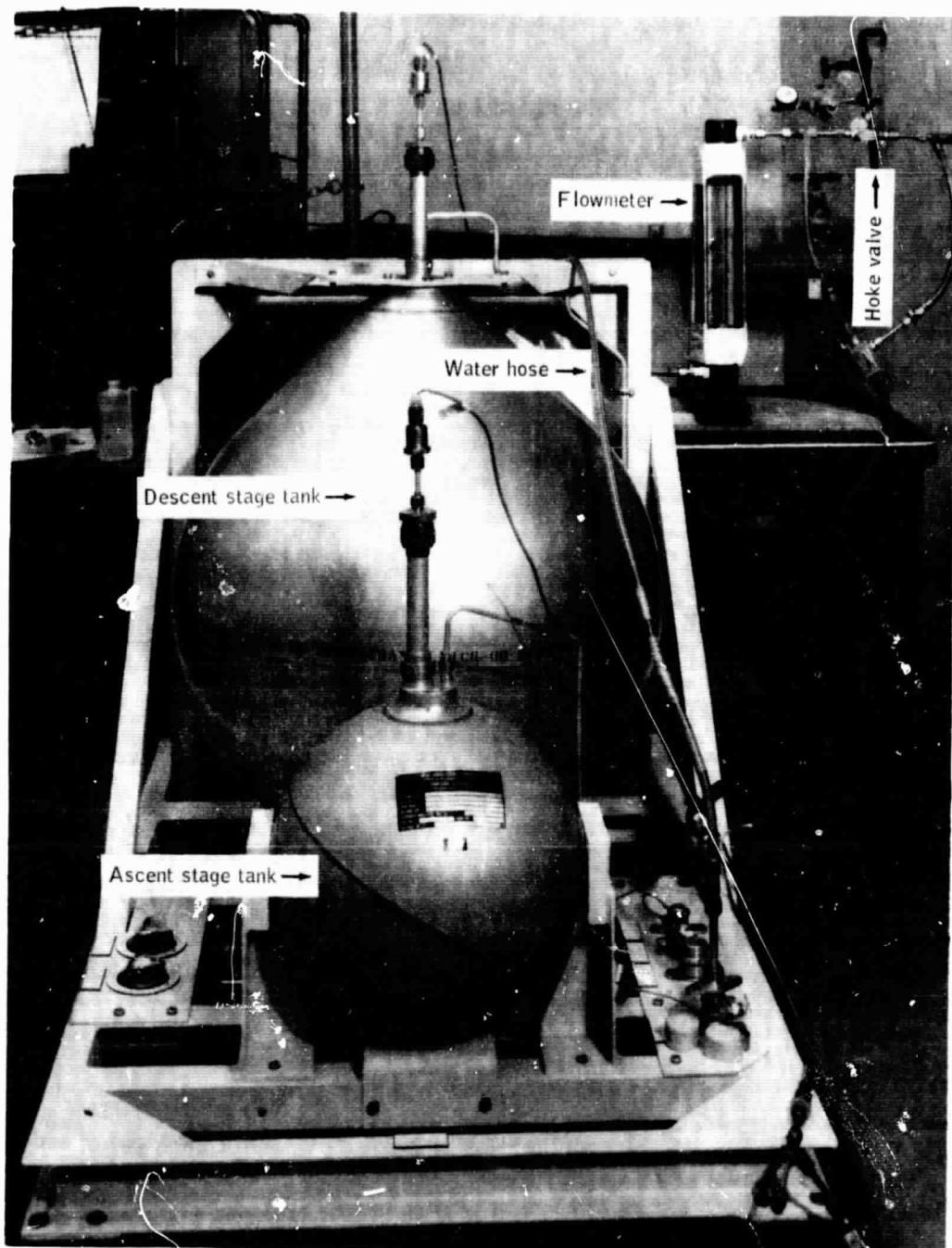


Figure 2.- The LM Water Management System simulator.

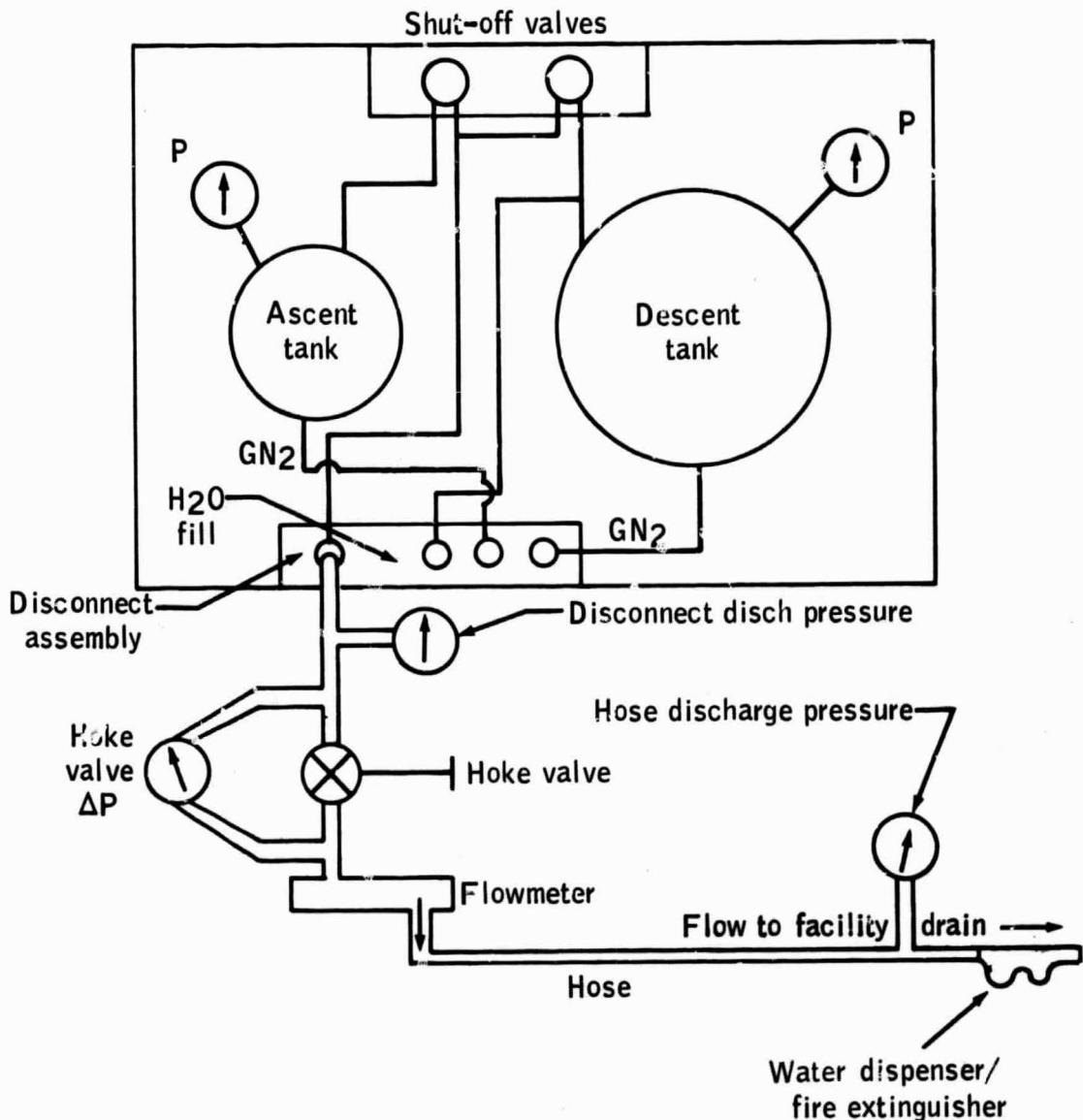


Figure 3 .- Schematic of LM Water Management System simulator.

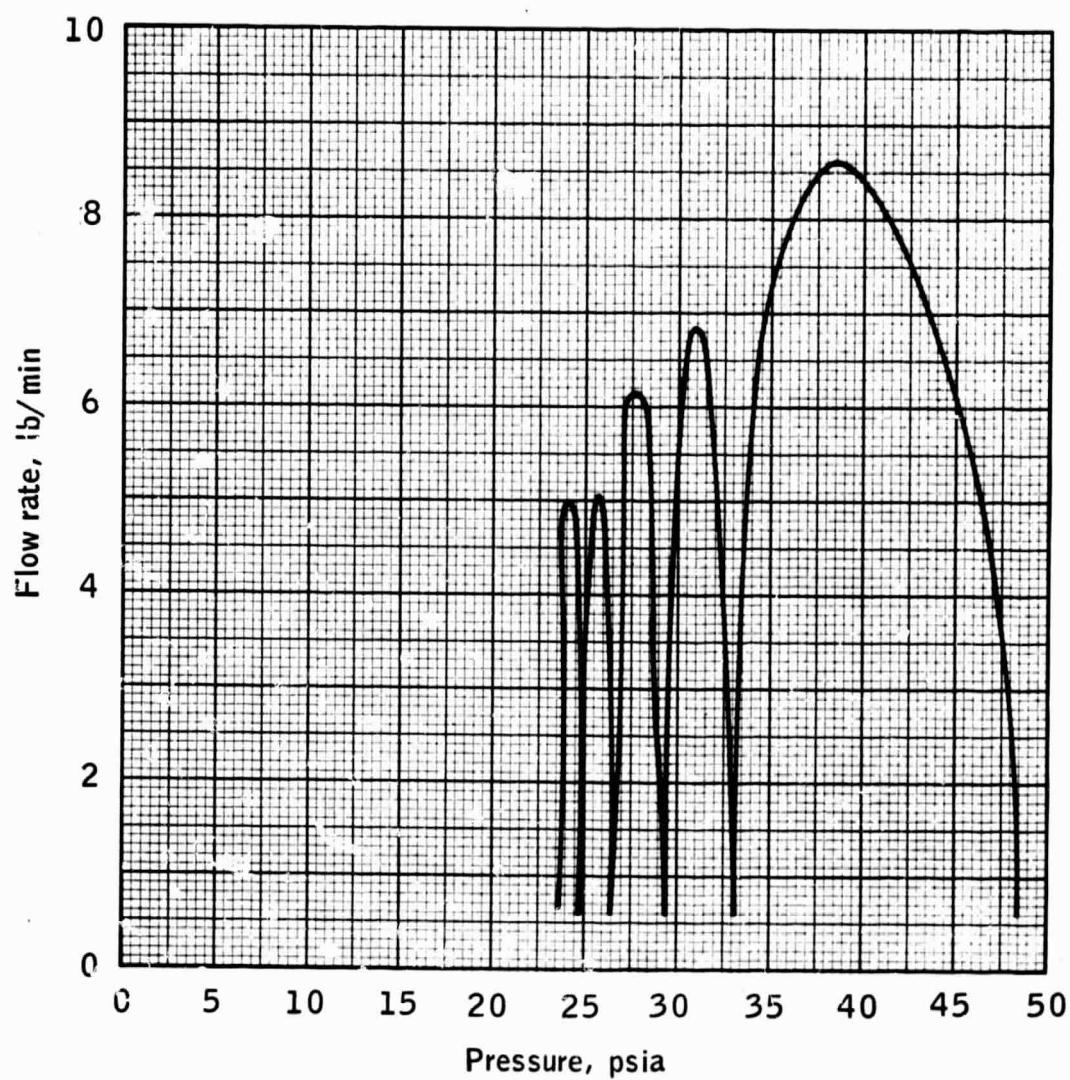


Figure 4.- Test A — flow rate versus descent tank pressure.

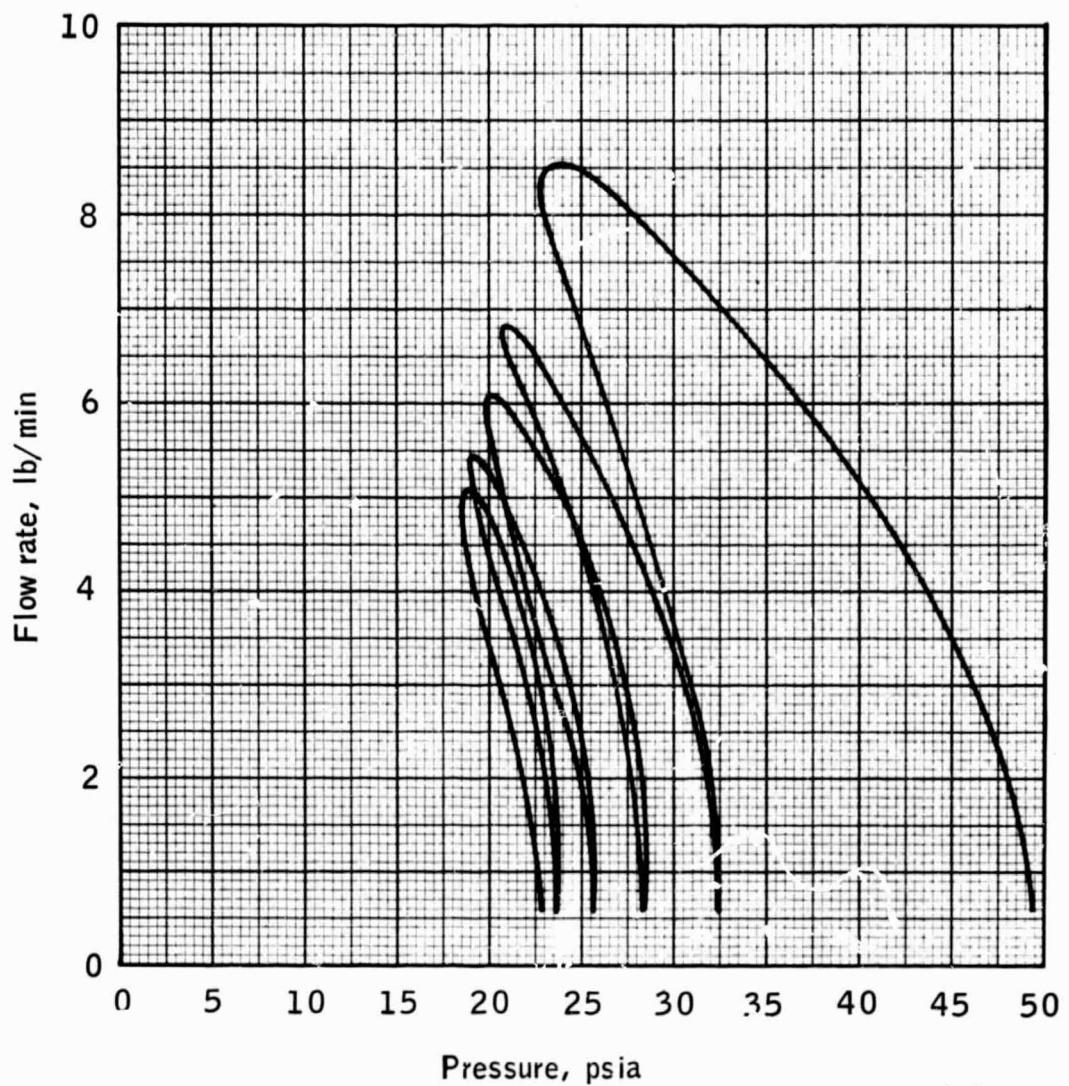


Figure 5.- Test A — flow rate versus disconnect discharge pressure.

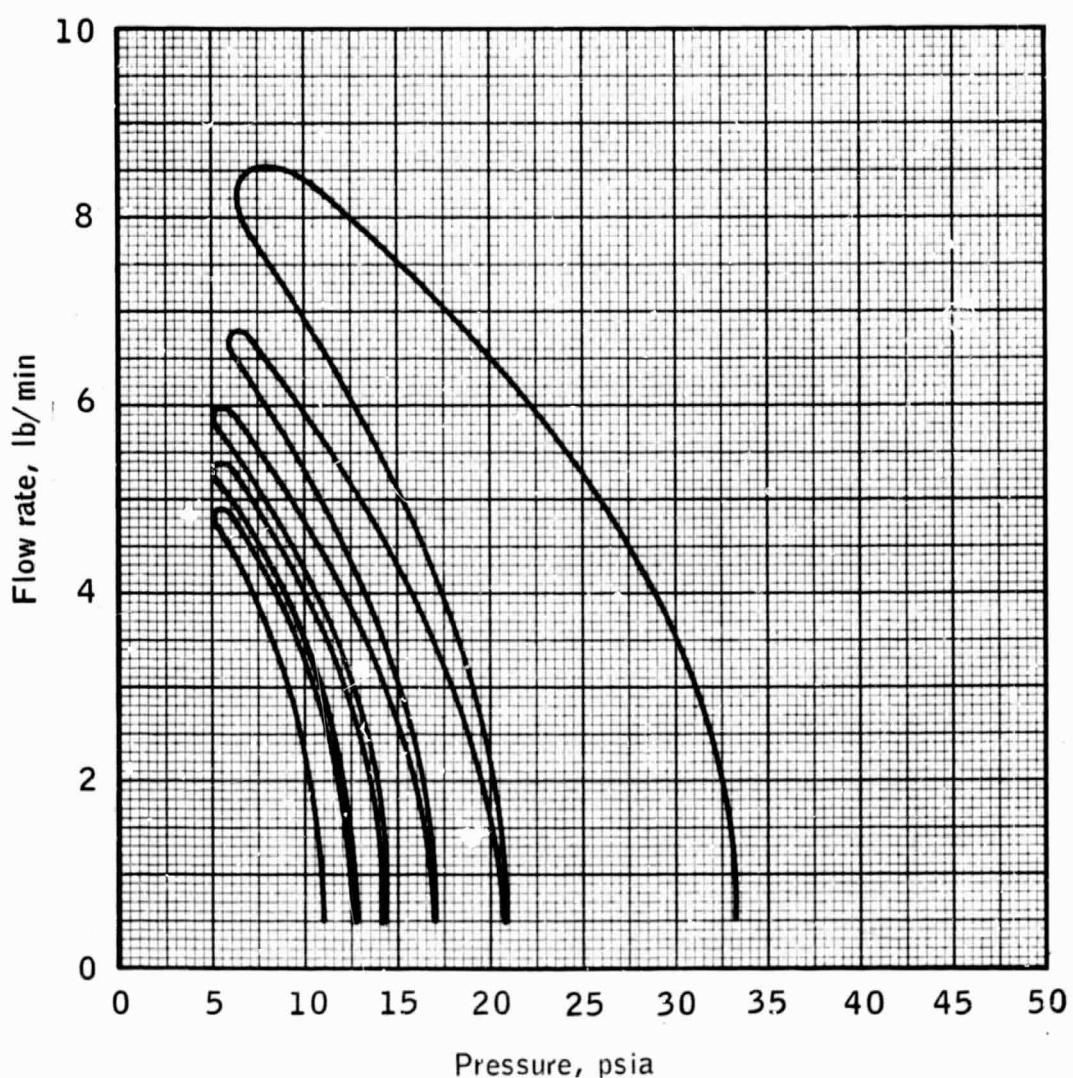


Figure 6.- Test A — flow rate versus Hooke valve pressure.

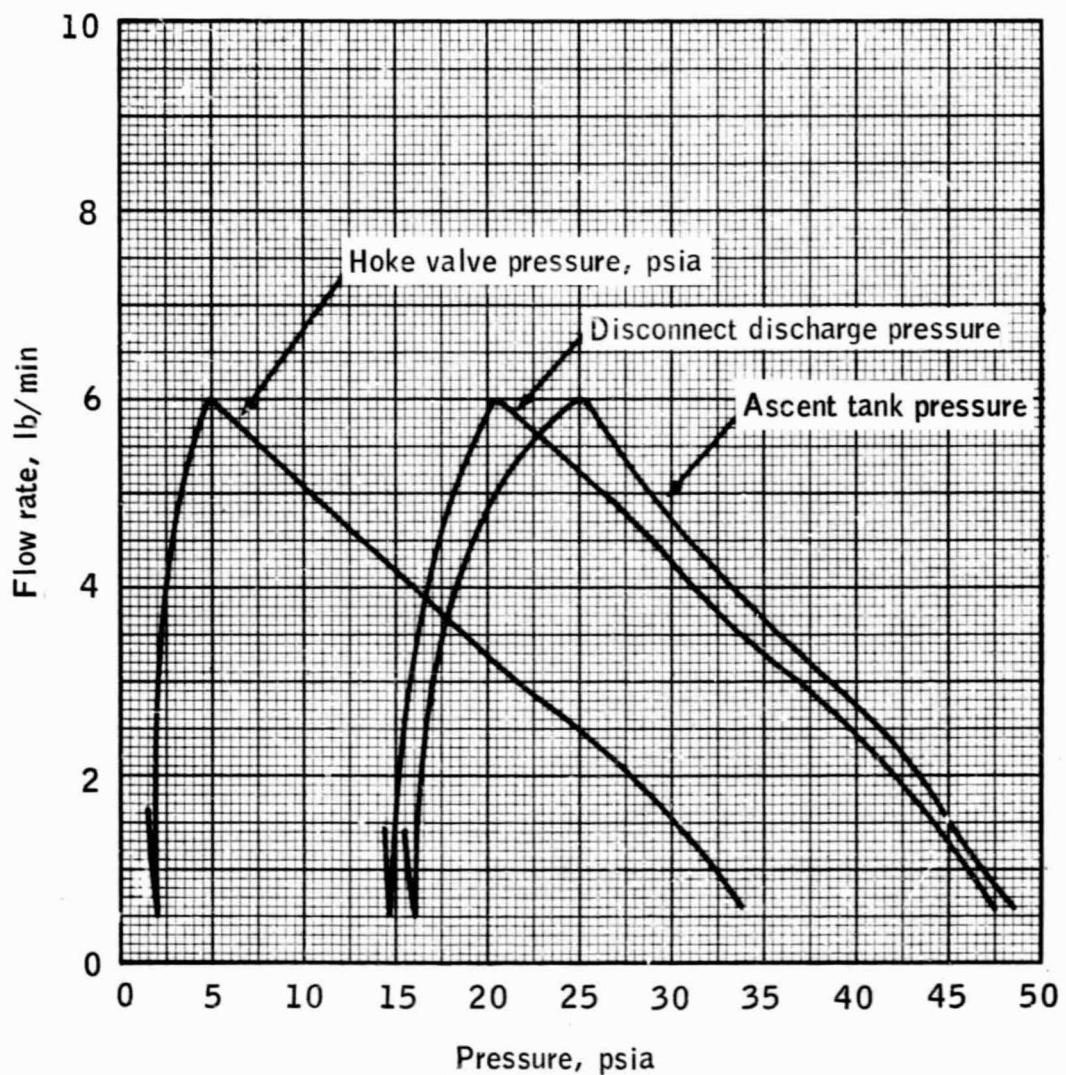


Figure 7.- Test B — flow rate versus ascent tank and line pressures .

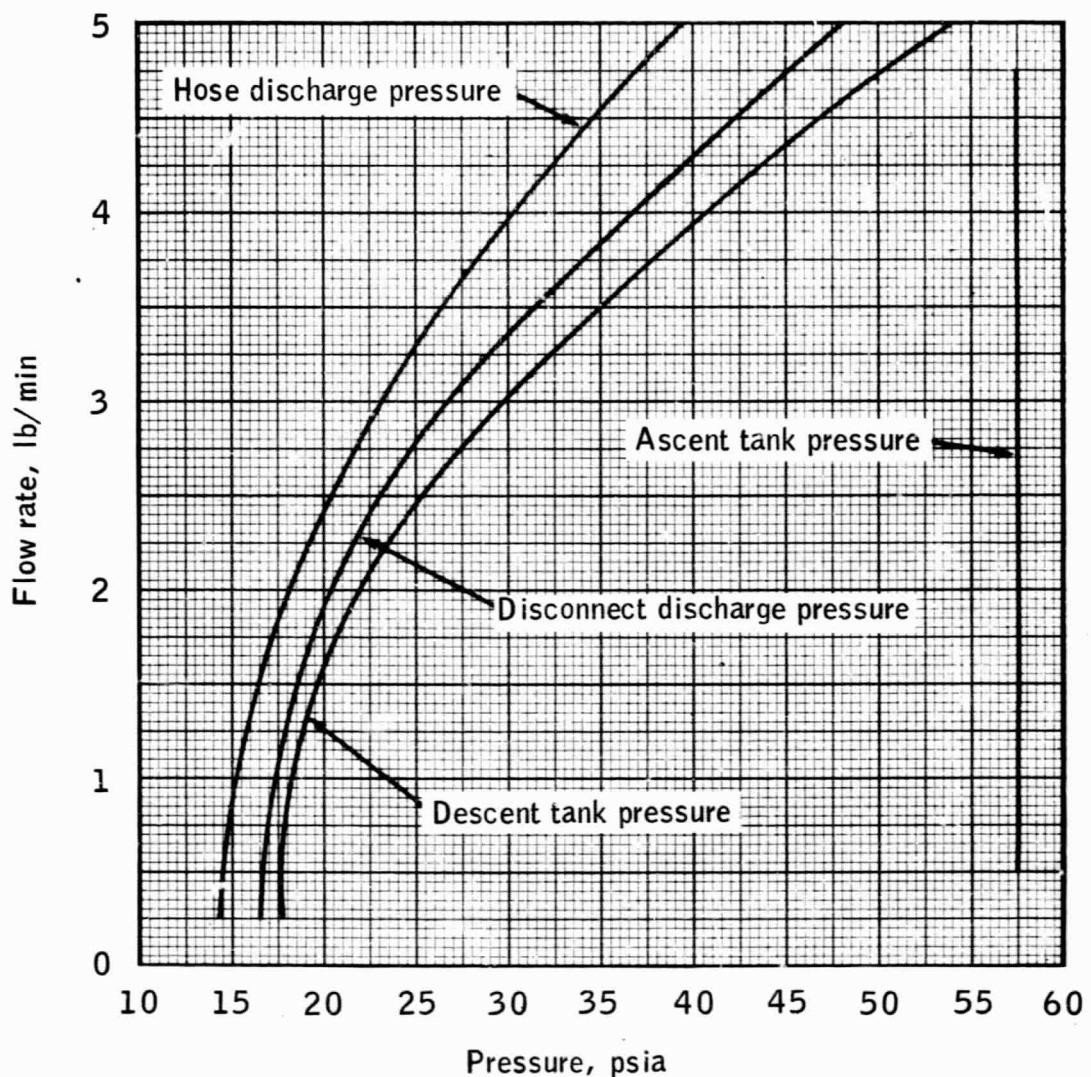


Figure 8.- Test C — flow rate versus descent tank and line pressures.

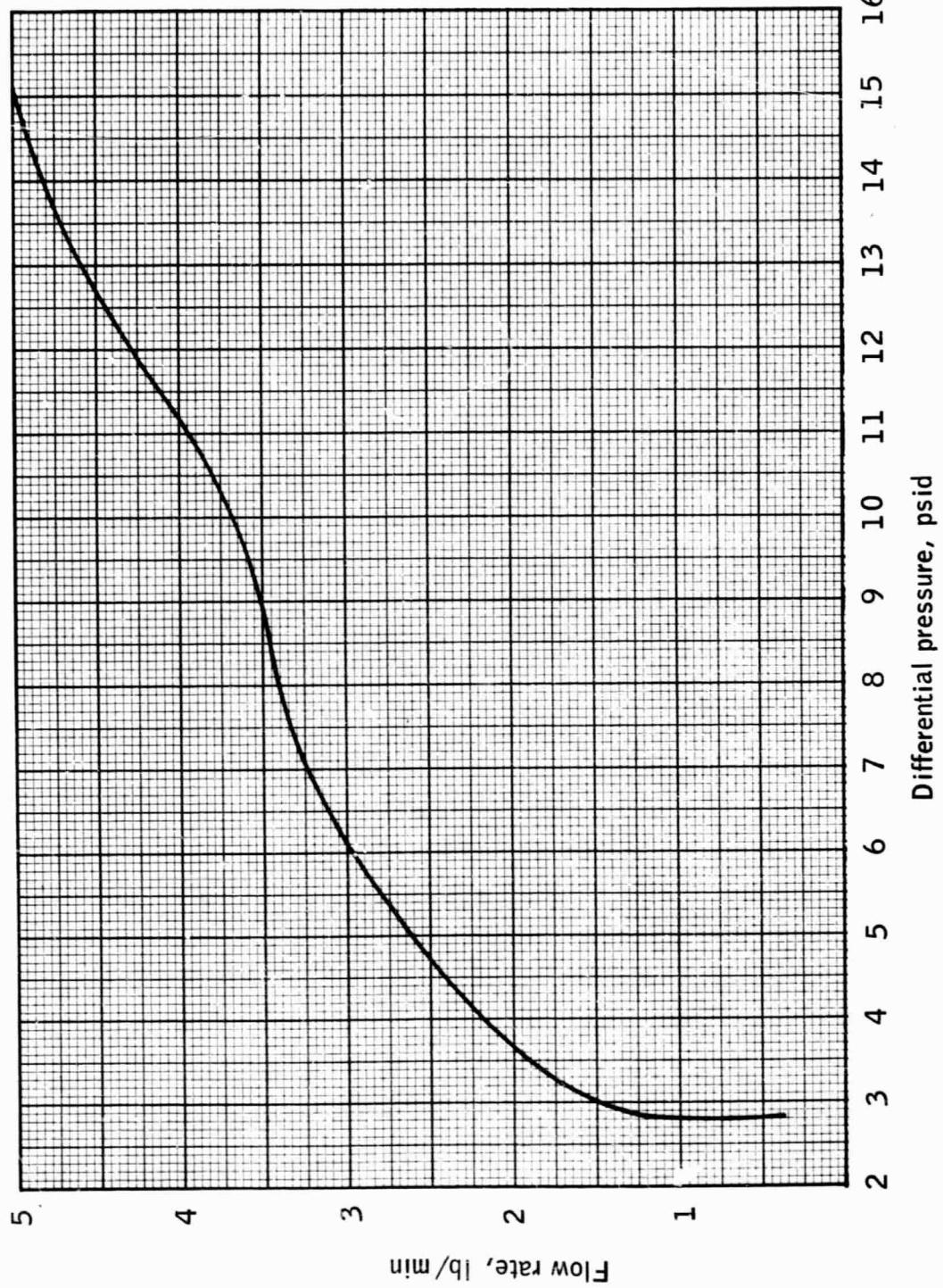


Figure 9.- Test C — flow rate versus descent tank-hose discharge differential pressure.

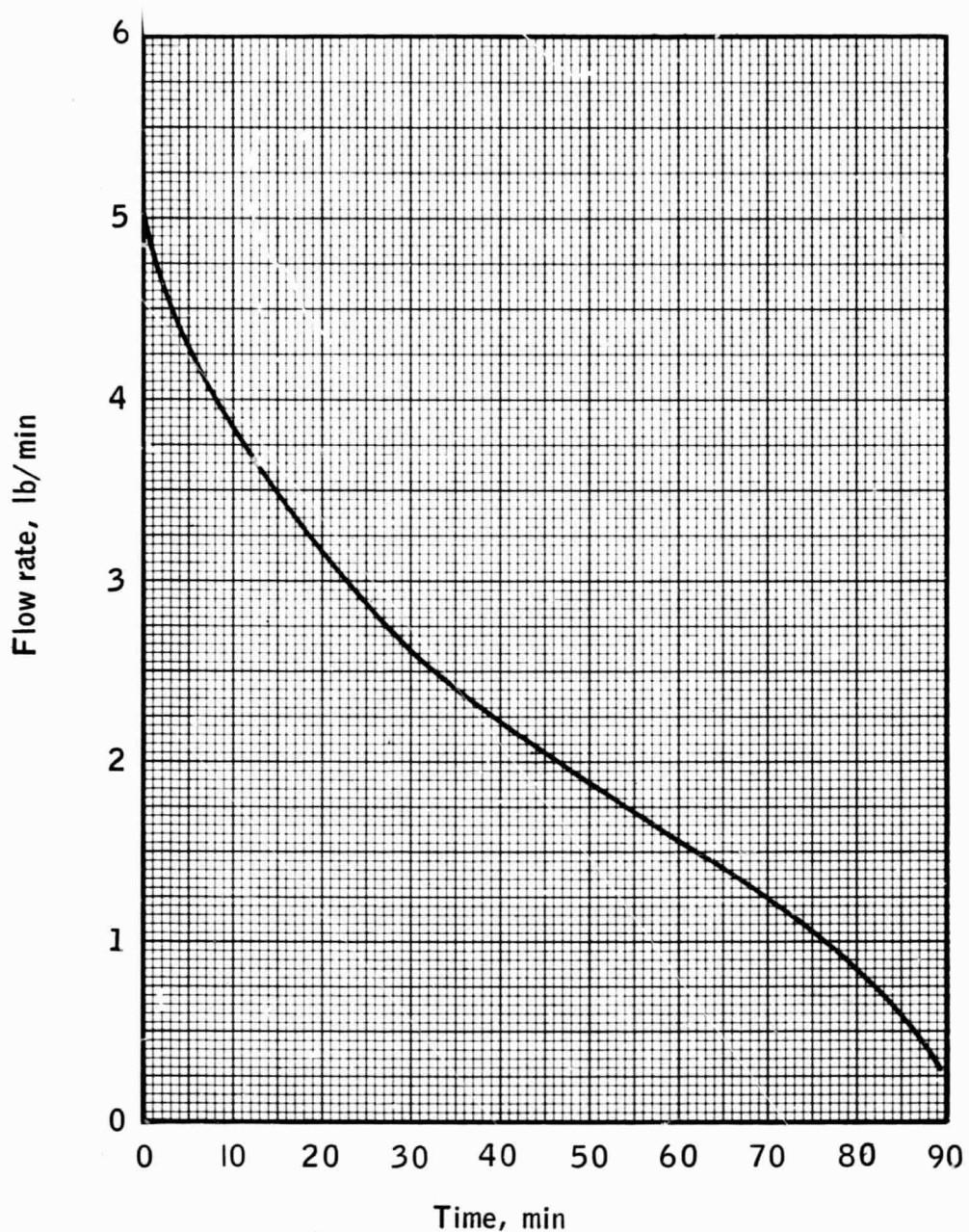


Figure 10.- Test C — line flow rate versus time.

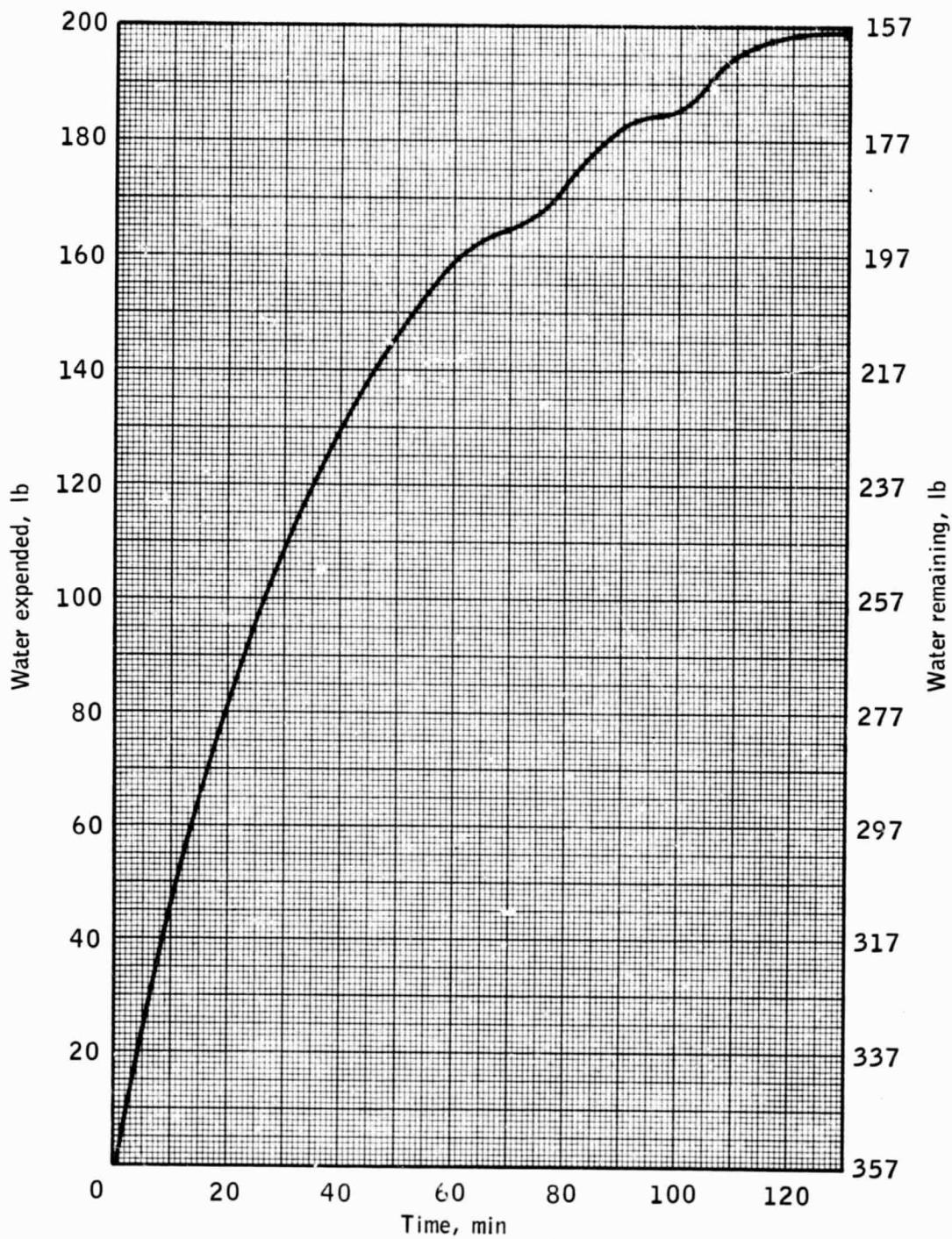


Figure 11.- Test C — descent tank water expended versus time.

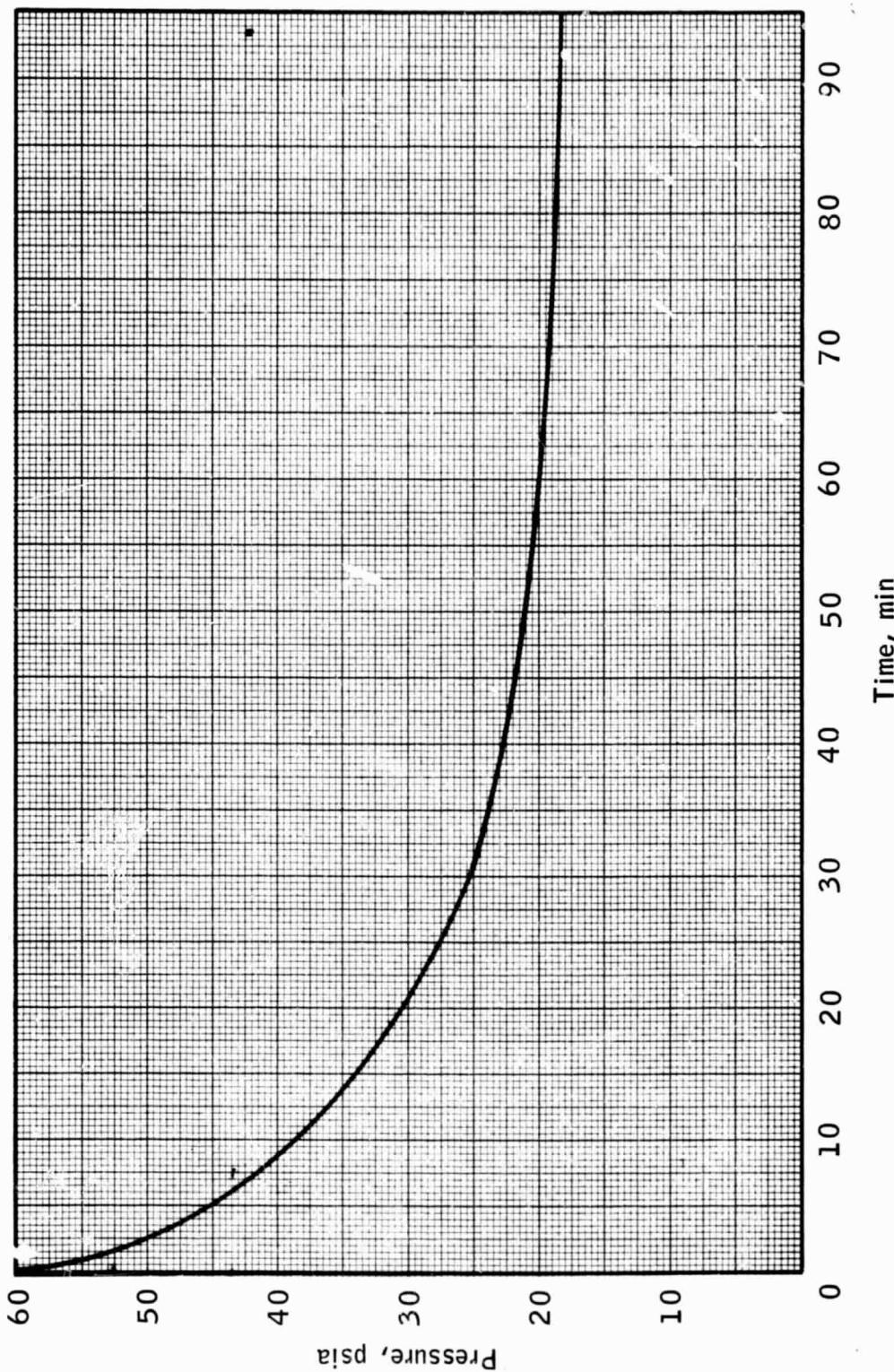


Figure 12.- Test C — descent tank pressure versus time.

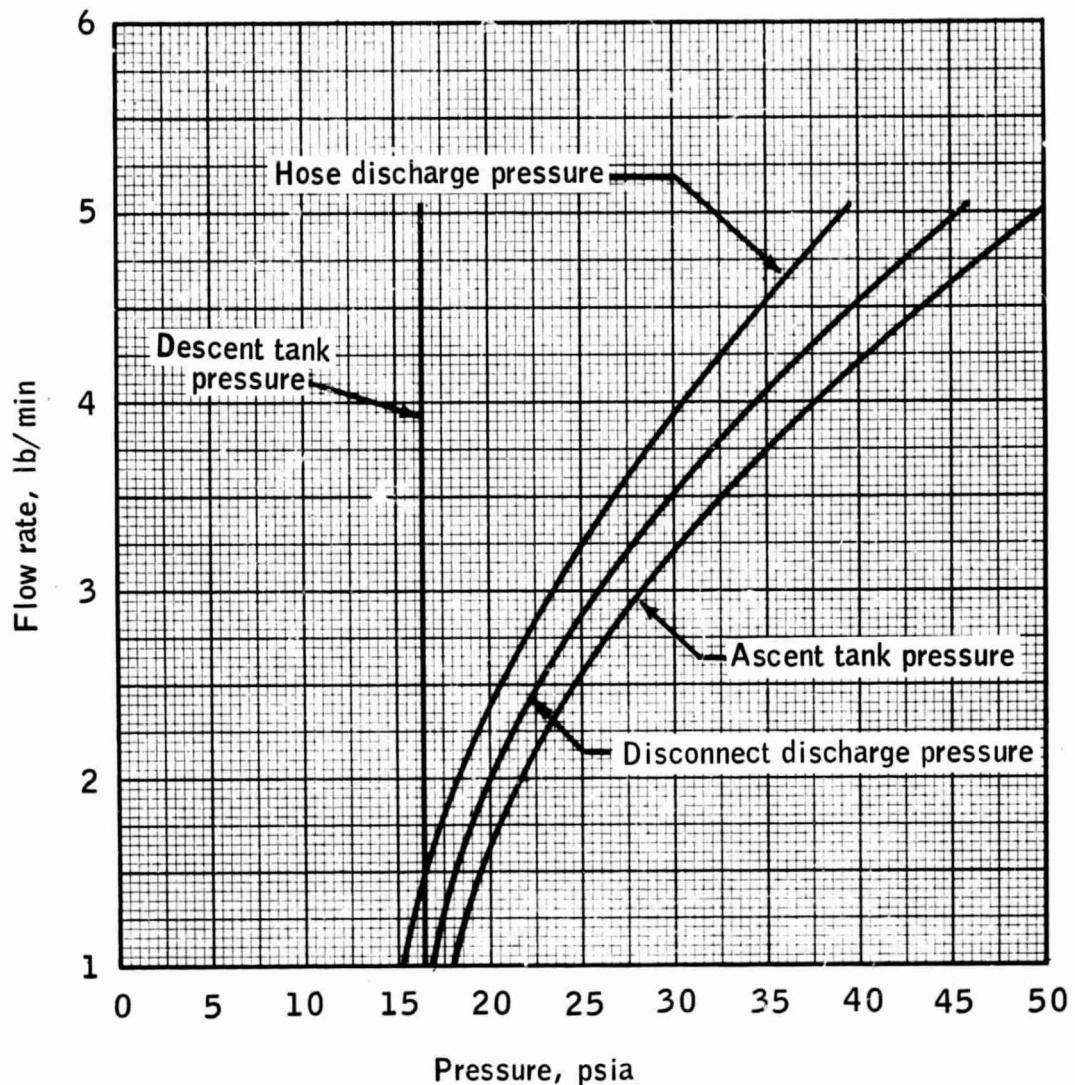


Figure 13.- Test D — flow rate versus ascent tank and line pressures.

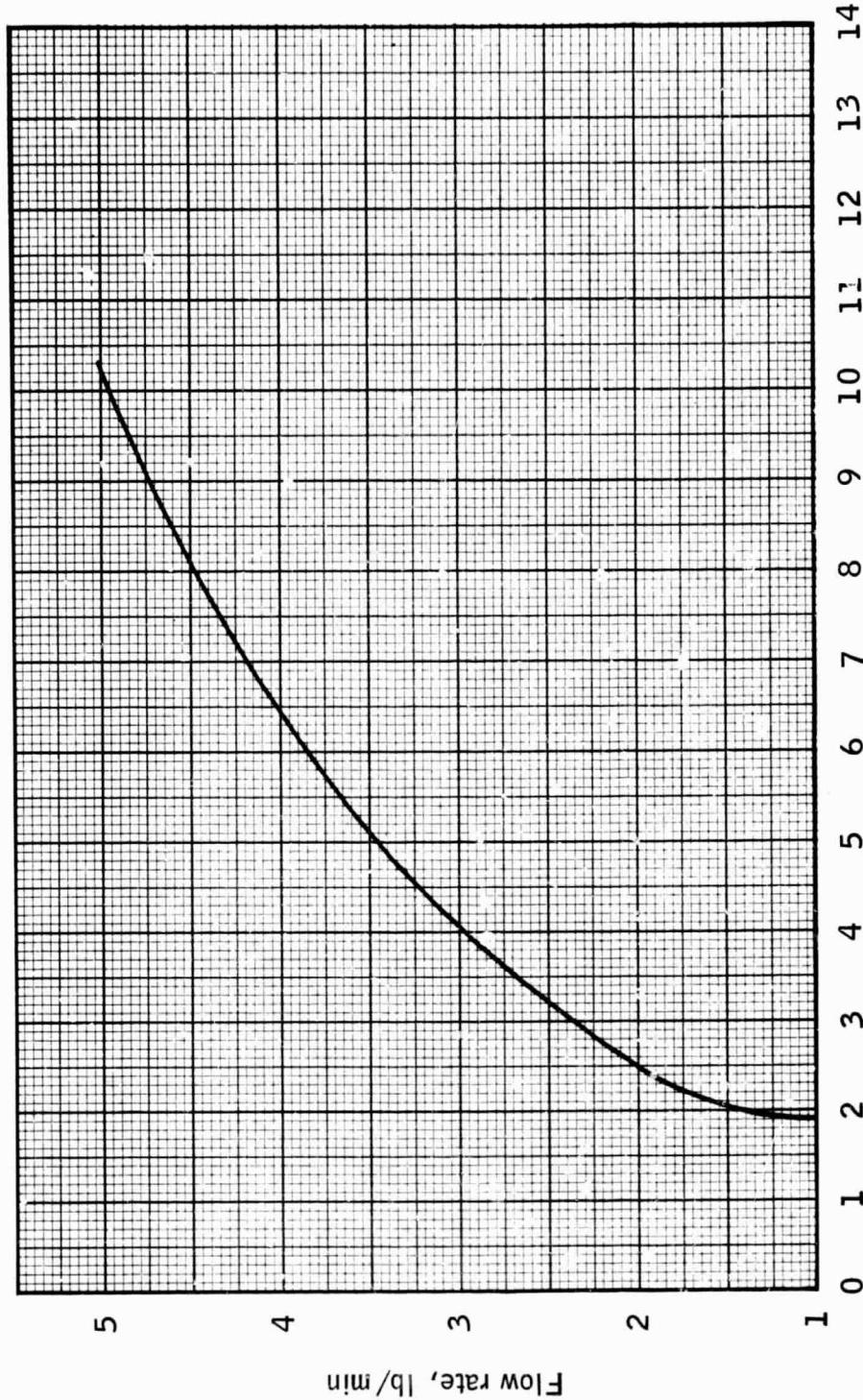


Figure 14.- Test D — flow rate versus ascent tank-hose discharge differential pressure.

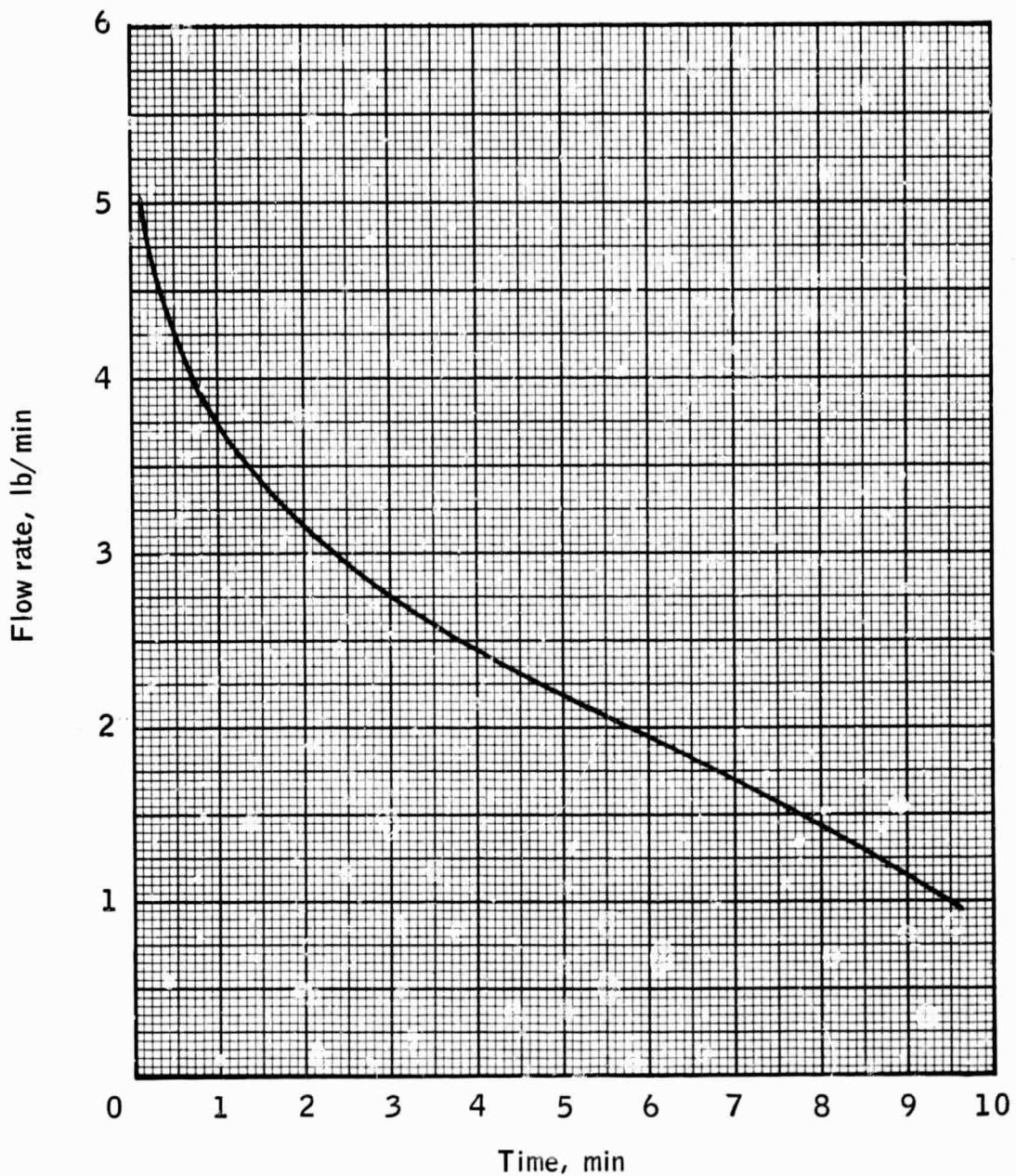


Figure 15.- Test D — line flow rate versus time.

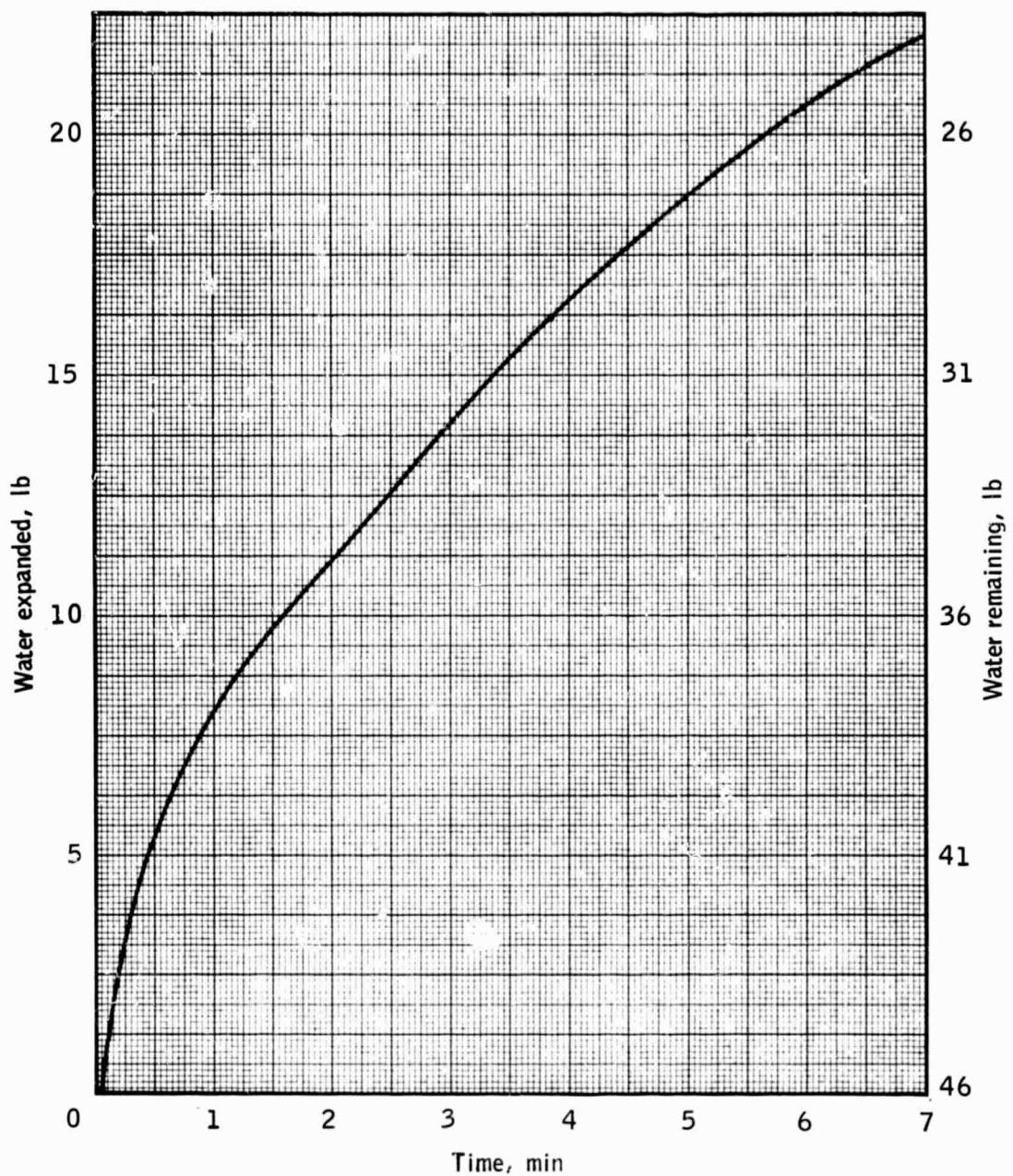


Figure 16 . - Test D — ascent tank water expended versus time.

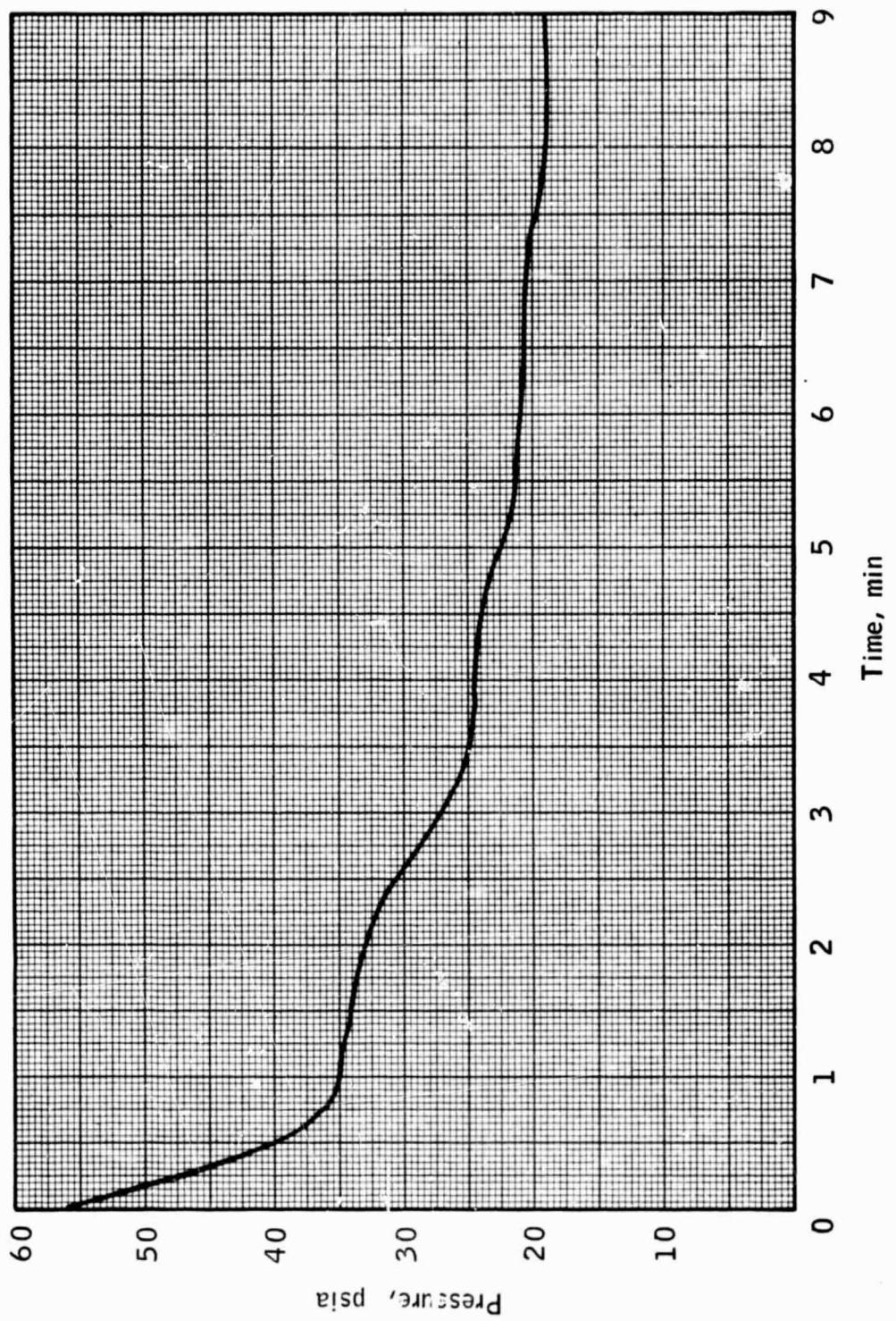


Figure 17.- Test D — ascent tank pressure versus time.

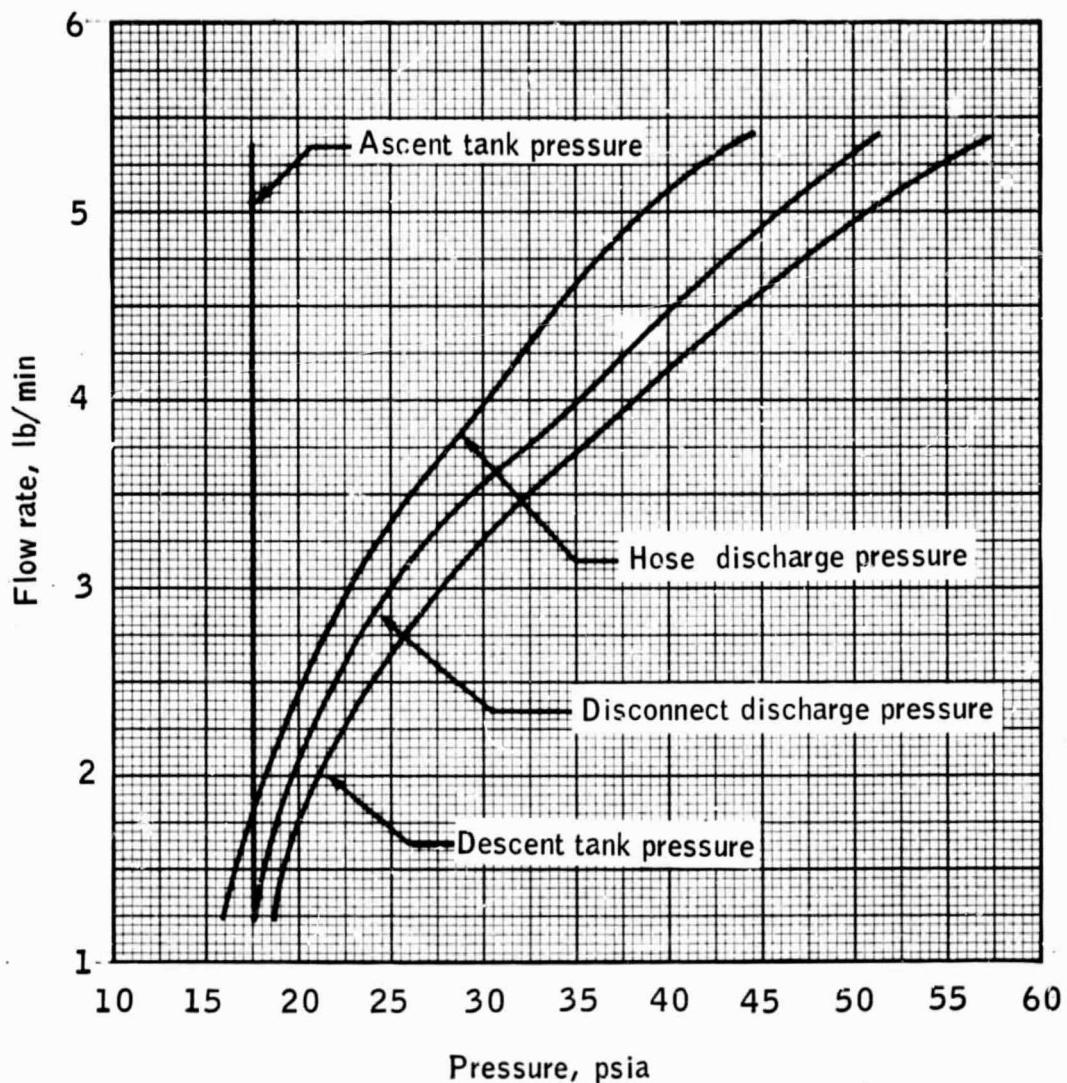


Figure 18.- Test E — flow rate versus descent tank and line pressures.

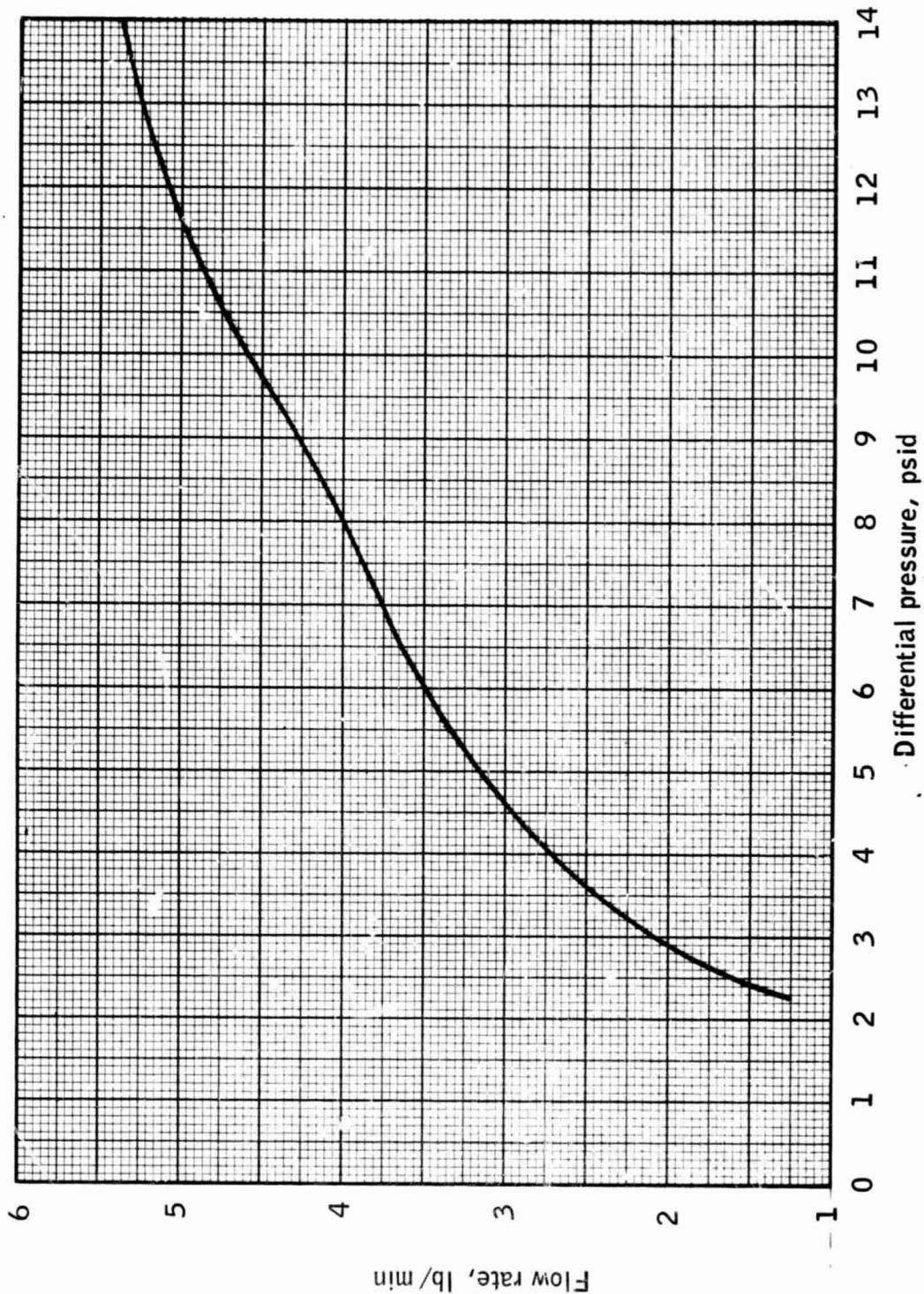


Figure 19.- Test E — flow rate versus descent tank-hose discharge differential pressure.

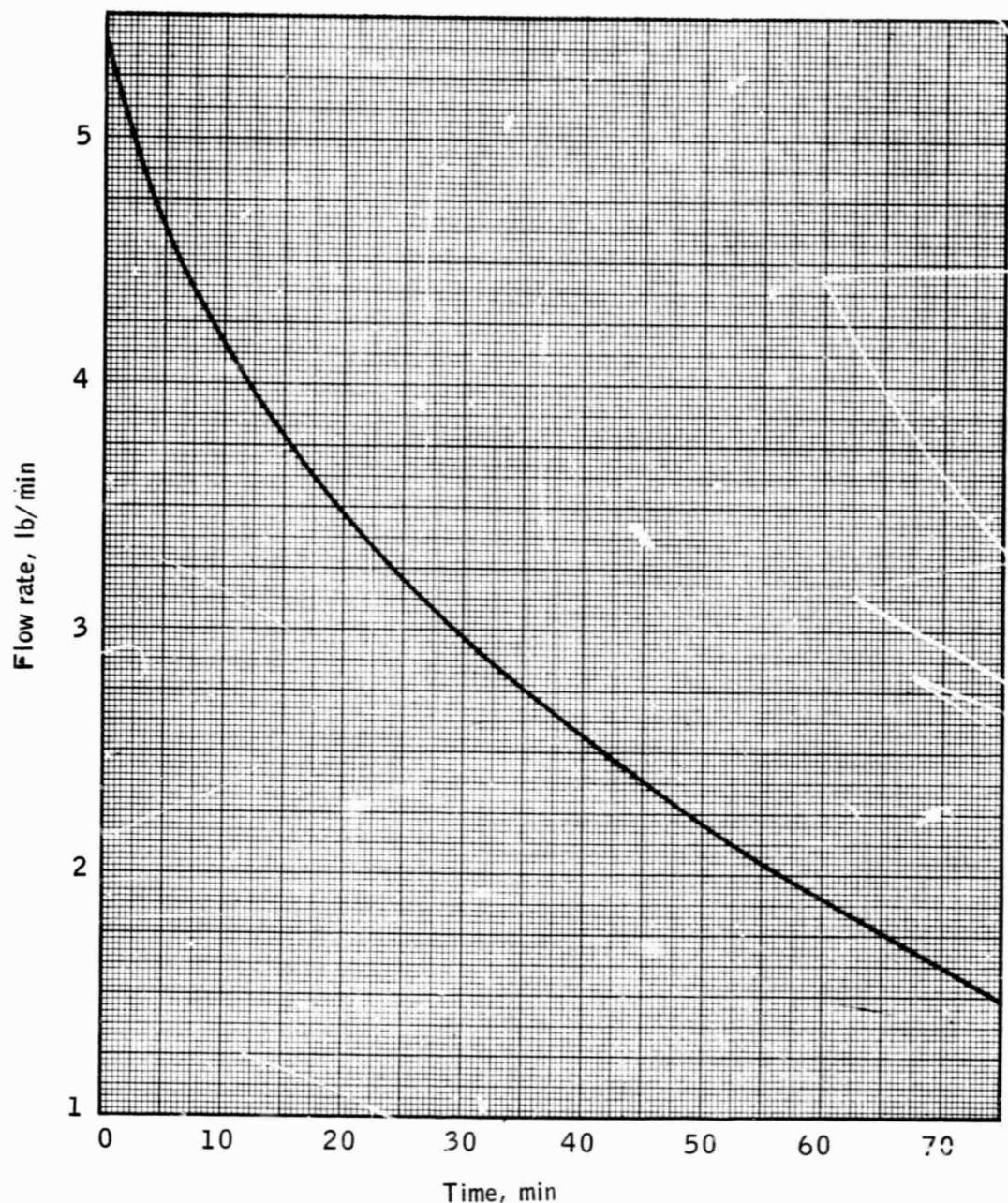


Figure 20.- Test E — line flow rate versus time.

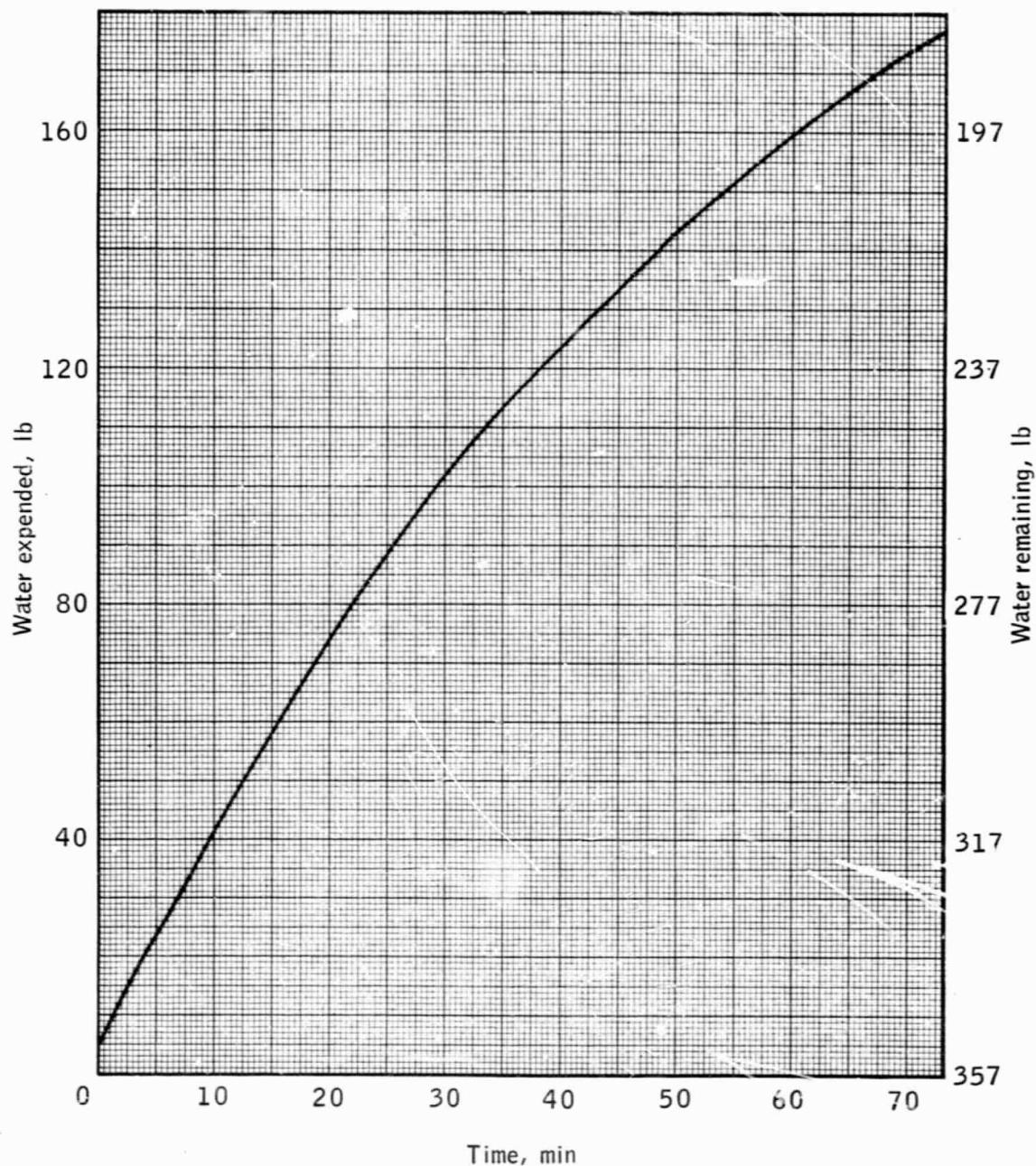


Figure 21.- Test E — descent tank water expended versus time.

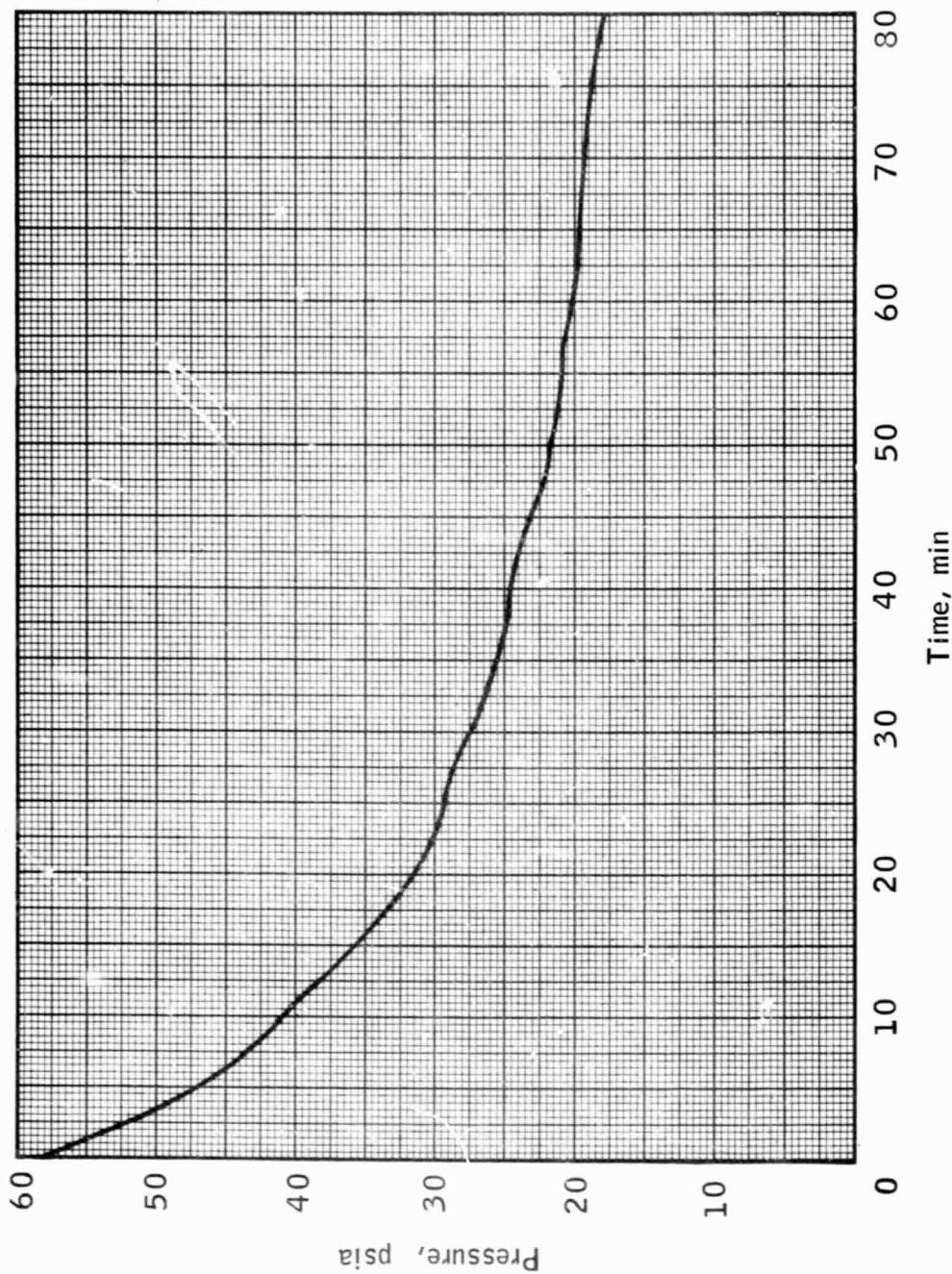


Figure 22 .- Test E — descent tank pressure versus time.

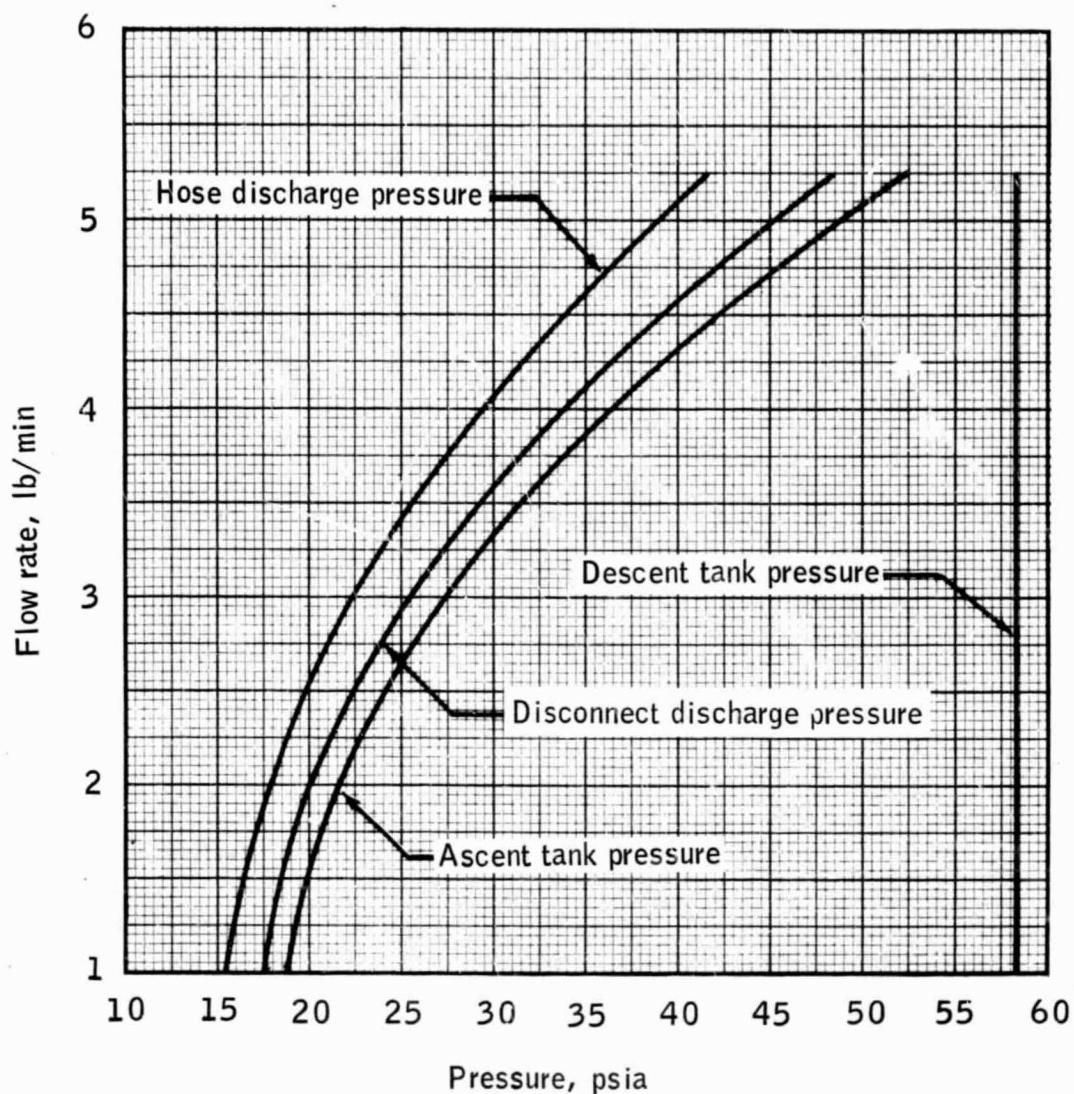


Figure 23.- Test F — flow rate versus ascent tank and line pressures.

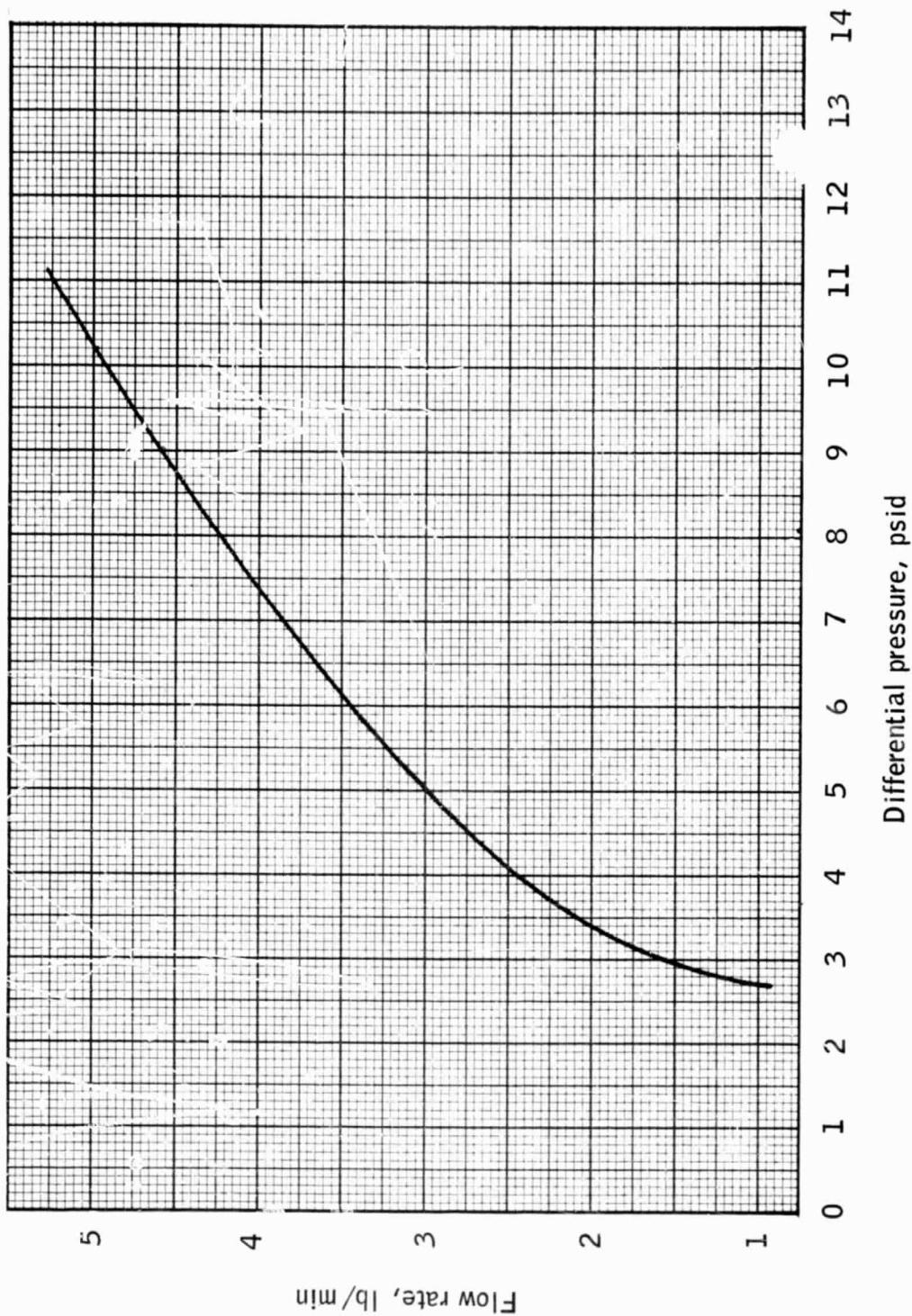


Figure 24.- Test F — flow rate versus ascent tank-hose discharge differential pressure.

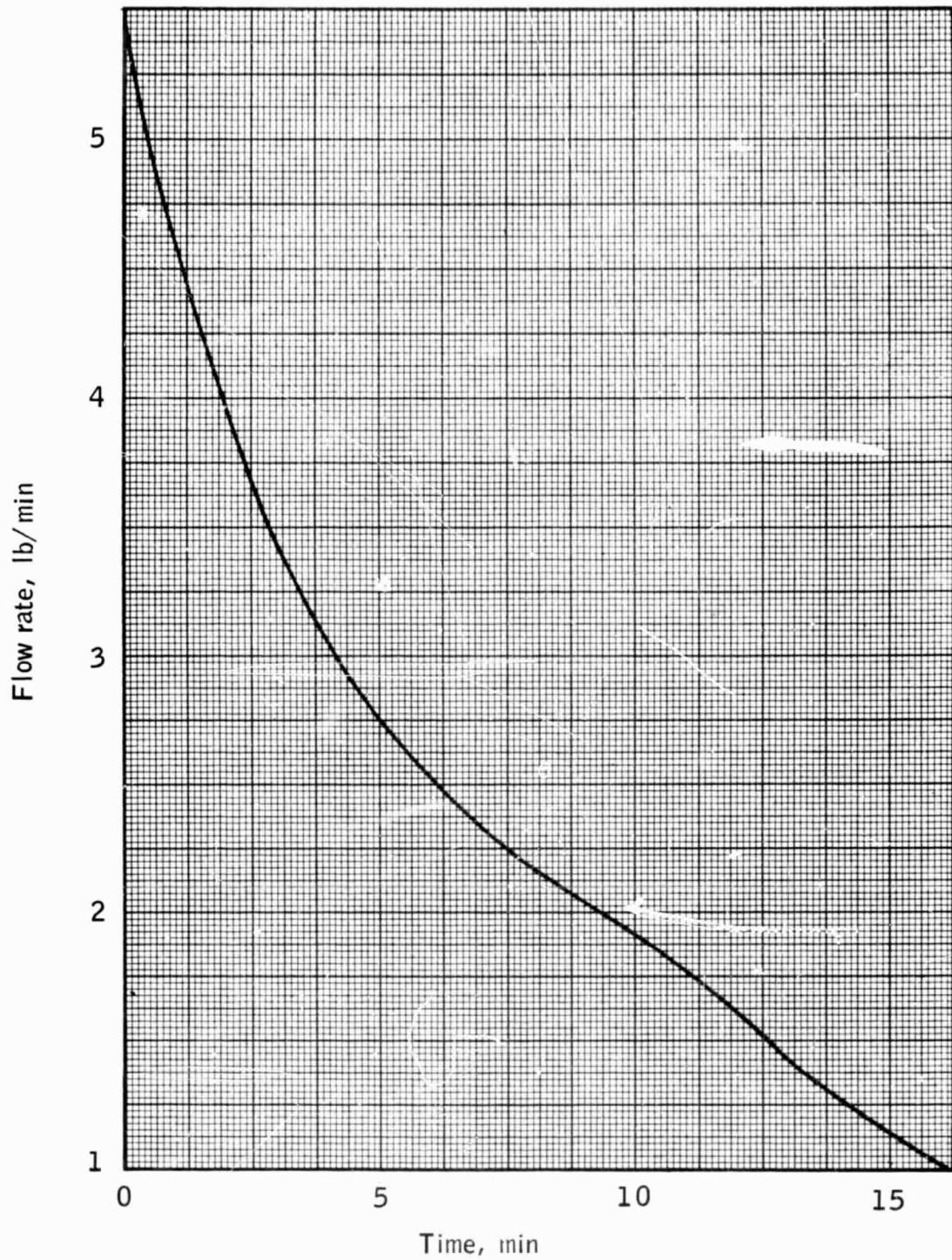


Figure 25.- Test F — line flow rate versus time.

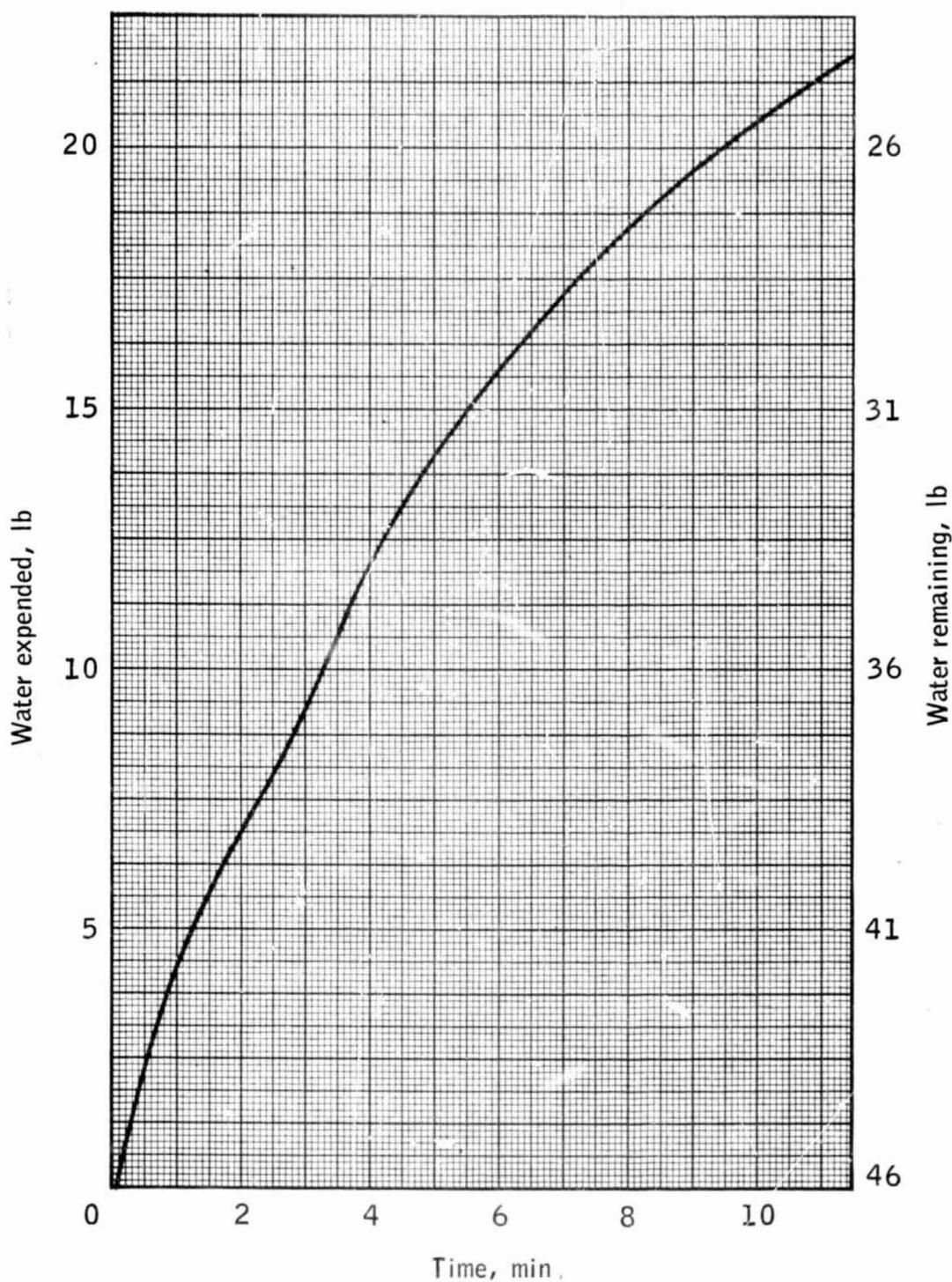


Figure 26.- Test F — ascent tank water expended versus time.

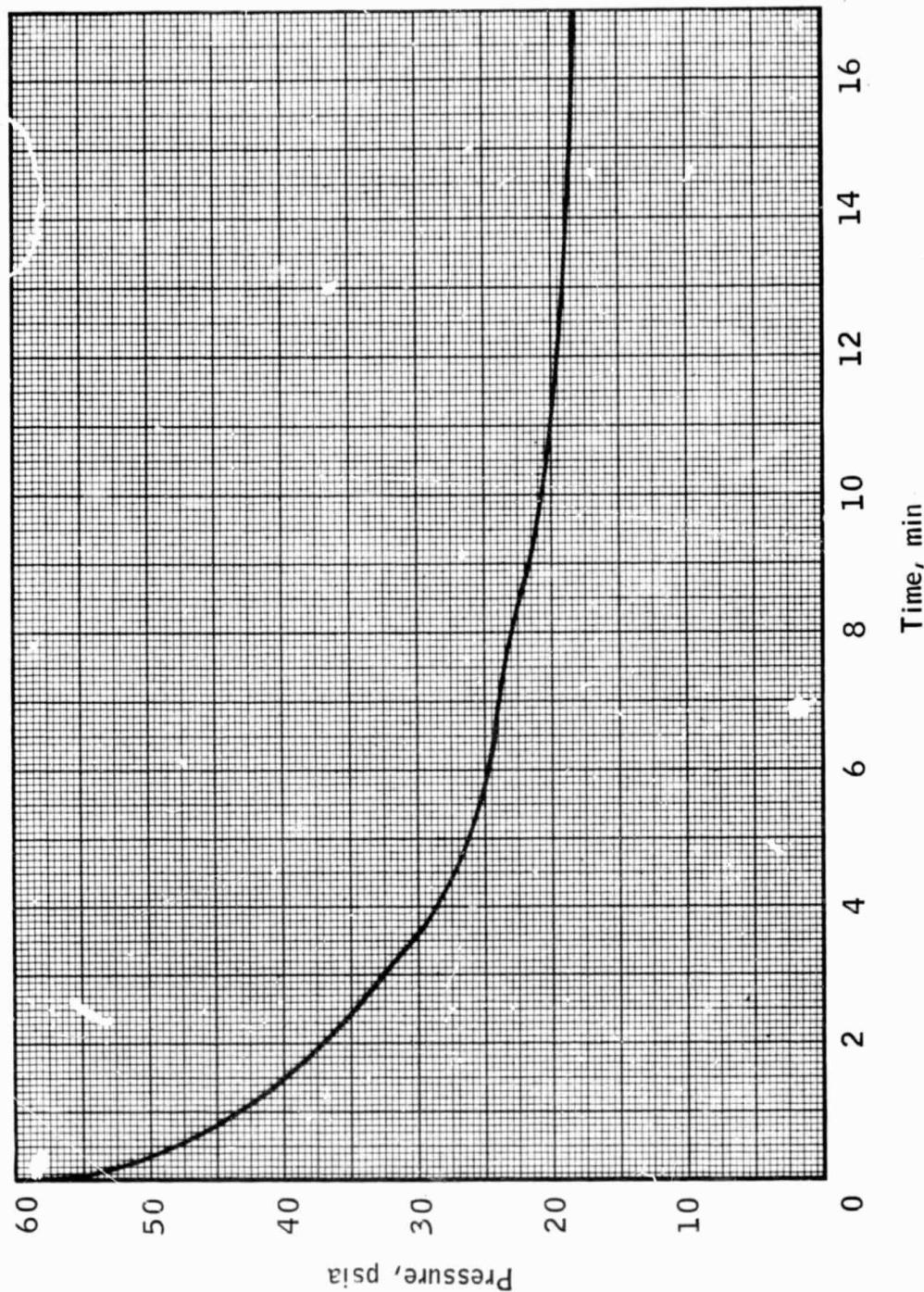


Figure 27 .- Test F — ascent tank pressure versus time.

APPENDIX A

TEST DATA

TABLE A-I.- TEST A — CALIBRATION SWEEPS — DESCENT WATER TANK WITHOUT  
WATER DISPENSER/FIRE EXTINGUISHER, WITH HOKE VALVE

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Hoke valve press., psid	Water-flow, percent	Hose disch. press., psia
Pretest calibrations			48.5	15.0	0.5	0.	14.8
Notes:		1	48.8	49.6	33.7	5.35	N/A
		2	48.8	49.6	33.0	9.11	
		3	48.8	49.6	32.6	10.7	
		4	48.7	47.7	32.5	21.4	
		5	48.0	46.0	31.0	32.1	
		6	47.2	43.3	28.0	42.8	
		7	46.2	40.8	23.8	53.5	
		8	44.7	36.8	20.0	64.2	
		9	43.2	33.0	16.7	74.9	
		10	41.5	28.0	12.0	85.6	
		11	39.2	25.0	7.5	92.0	
		12	36.5	23.5	7.0	85.6	
		13	35.0	24.3	9.3	74.9	
		14	34.4	26.3	12.5	64.2	
		15	34.1	27.8	15.2	53.5	
		16	34.1	29.2	17.2	42.8	
		17	33.6	30.7	18.7	32.1	
		18	33.4	31.4	20.0	21.4	
		19	33.4	31.6	21.0	10.7	
		20	33.4	32.1	21.5	9.11	
		21	33.3	32.1	22.0	5.35	
		22	33.3	33.0	20.5	5.35	
		23	33.3	33.0	20.5	9.11	
		24	33.0	33.0	20.4	10.7	
		25	32.9	32.2	19.0	21.4	
		26	32.9	30.8	17.5	32.10	

TABLE A-I.- TEST A — CALIBRATION SWEEPS — DESCENT WATER TANK WITHOUT  
WATER DISPENSER/FIRE EXTINGUISHER, WITH HOKE VALVE - Continued

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Hoke valve press., psid	Water-flow, percent	Hose disch. press., psia
Pretest calibrations			48.5	15.0	0.5	0.	14.8
Notes:		27	32.8	29.3	15.5	42.8	N/A
		28	32.0	26.5	12.5	53.5	
		29	31.9	24.2	9.0	64.2	
		30	31.2	21.4	6.5	73.0	
		31	30.2	22.0	8.0	64.2	
		32	30.2	24.1	11.5	53.5	
		33	29.8	25.6	13.5	42.8	
		34	29.7	26.4	15.0	32.1	
		35	29.7	27.8	16.5	21.4	
		36	29.6	27.9	17.5	10.7	
		37	29.5	28.0	17.5	9.11	
		38	29.5	28.5	17.5	5.35	
		39	29.5	28.6	17.3	5.35	
		40	29.5	28.6	17.0	9.11	
		41	29.5	28.6	16.8	10.7	
		42	29.5	28.0	15.5	21.4	
		43	28.9	27.1	14.0	32.1	
		44	29.9	25.8	11.7	42.8	
		45	28.8	23.6	9.0	53.5	
		46	28.8	20.8	5.5	64.2	
		47	28.8	20.7	5.5	65.2	
		48	27.2	20.0	5.0	64.2	
		49	27.2	20.8	7.5	53.5	
		50	27.1	22.1	10.0	42.8	
		51	27.1	23.6	12.0	32.1	
		52	27.0	25.0	13.0	21.4	

TABLE A-I.- TEST A — CALIBRATION SWEEPS — DESCENT WATER TANK WITHOUT  
WATER DISPENSER/FIRE EXTINGUISHER. WITH HOKE VALVE - Concluded

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Hoke valve press., psid	Water-flow, percent	Hose disch. press., psia
Pretest calibrations			48.5	15.0	0.5	0.	14.8
Notes:		53	26.8	25.1	14.0	10.7	N/A
		54	26.6	25.7	14.0	9.11	
		55	26.6	25.8	14.0	5.35	
		56	26.6	25.8	14.0	5.35	
		57	26.6	25.8	14.0	9.11	
		58	26.6	25.8	13.9	10.7	
		59	26.5	25.2	12.5	21.4	
		60	26.5	24.4	11.0	32.1	
		61	26.4	23.0	9.0	42.8	
		62	26.4	20.8	6.5	53.5	
		63	26.3	19.3	5.0	58.0	
		64	24.9	23.6	13.0	5.35	
		65	24.9	23.6	12.5	9.11	
		66	24.9	23.6	12.5	10.7	
		67	24.9	23.5	11.5	21.4	
		68	24.9	22.9	10.0	32.1	
		69	24.9	21.4	8.0	42.8	
		70	24.8	19.3	5.5	53.5	
		71	24.1	18.7	5.0	54.5	
		72	24.1	18.7	4.8	53.5	
		73	24.0	19.1	7.0	42.8	
		74	24.0	20.6	9.0	32.1	
		75	24.0	21.3	10.0	21.4	
		76	24.0	22.8	11.0	10.7	
		77	24.0	22.8	11.0	9.11	
		78	23.9	22.8	11.2	5.35	

TABLE A-II.- TEST B — CALIBRATION SWEEPS — ASCENT WATER TANK WITHOUT  
WATER DISPENSER/FREE EXTINGUISHER, WITH HOKE VALVE

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Hoke valve press., psid	Water-flow, percent	Hose disch. press., psia
Pretest calibrations			49.0	15.0	0.5	0.	14.8
Notes:		1	47.8	48.8	34.0	5.35	N/A
		2	46.8	47.4	32.5	9.11	
		3	45.5	46.2	31.5	10.7	
		4	43.0	43.1	28.0	21.4	
		5	37.2	36.8	21.5	32.10	
		6	33.2	31.6	16.5	42.8	
		7	29.0	26.3	11.0	53.5	
		8	25.3	20.7	5.0	64.2	
		9	22.6	18.4	3.5	58.0	
		10	20.0	17.8	3.0	53.5	
		11	18.8	17.7	3.0	42.8	
		12	17.0	16.1	2.0	32.10	
		13	16.5	16.1	2.0	21.4	
		14	15.5	16.1	2.0	10.7	
		15	15.5	16.1	2.0	9.11	
		16	15.2	16.1	2.0	5.35	
		17	15.5	14.8	2.5	5.35	
		18	15.5	14.8	2.5	9.11	
		19	15.2	14.8	2.5	10.7	
		20	15.2	14.8	2.0	16.0	

TABLE A-III.- TEST C — DESCENT WATER TANK WITH WATER DISPENSER/  
FIRE EXTINGUISHER, WITH HOKE VALVE

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Hoke valve press., psid	Water-flow, percent	hose disch. press., psia
Pretest calibrations			58.0	14.7	0.	0.	14.7
Notes:							
7/16/68	5	1	55.4	49.0	1.85	54.0	40.0
Start time 3:58 pm	10	2	54.8	48.3	1.83	54.0	39.5
Stop 4:58 pm	15	3	54.0	48.0	1.80	53.5	39.2
7/19/68	20	4	53.0	48.0	1.79	53.0	39.0
Start 9:20 am	25	5	53.0	47.3	1.78	53.0	38.8
Stop 9:50 am	30	6	52.9	47.3	1.77	53.0	38.5
Cone of spray approx 4 to 6 feet diameter at 6 feet away	35	7	52.2	47.0	1.75	52.5	38.4
	40	8	52.0	46.8	1.74	52.5	38.3
	45	9	51.5	46.2	1.72	52.0	38.0
	50	10	51.5	46.0	1.72	52.0	37.8
	65	11	51.2	46.0	1.70	51.75	37.3
	80	12	50.5	45.3	1.67	51.0	37.0
	95	13	49.7	44.7	1.64	50.75	36.5
	110	14	49.1	44.1	1.60	50.0	36.2
	125	15	49.0	44.0	1.59	50.0	35.8
	140	16	48.3	43.1	1.58	49.5	35.3
	170	17	47.5	43.1	1.54	49.0	34.3
	200	18	46.3	41.2	1.47	48.0	34.0
	230	19	45.8	41.0	1.45	47.5	33.4
	260	20	45.0	41.0	1.40	47.0	33.0
	290	21	44.3	40.3	1.37	46.2	32.5
	320	22	43.8	39.6	1.35	46.0	32.0
Notes:	350	23	43.3	39.0	1.33	45.5	31.6
	380	24	42.6	38.9	1.30	45.0	31.3
	410	25	42.6	38.3	1.28	44.2	31.0
	440	26	42.0	38.1	1.26	44.0	30.8

TABLE A-III.- TEST C — DESCENT WATER TANK WITH WATER DISPENSER/  
FIRE EXTINGUISHER, WITH HOKE VALVE - Continued

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Hoke valve press., psid	Water- flow, percent	Hose disch. press., psia
Pretest calibrations			58.0	14.7	0.	0.	14.7
Notes:	470	27	41.2	37.4	1.25	43.0	30.3
	500	28	41.0	37.4	1.23	42.5	30.0
	530	29	40.4	36.1	1.20	42.0	29.5
	560	30	40.1	36.1	1.18	41.8	29.0
	590	31	39.6	36.0	1.10	41.4	28.5
	620	32	38.6	34.9	1.14	41.0	28.4
	650	33	38.0	34.7	1.10	40.5	28.2
	680	34	37.9	34.7	1.08	40.0	27.9
	710	35	37.2	34.0	1.07	40.0	27.6
	740	36	37.0	33.3	1.06	39.5	27.4
	770	37	36.5	33.1	1.05	39.2	27.2
	800	38	36.2	33.1	1.04	38.9	26.9
	830	39	35.7	32.3	1.03	38.0	26.8
	860	40	35.4	31.9	1.0	38.0	26.8
	890	41	34.9	31.9	0.98	37.5	26.7
	920	42	34.8	31.8	.97	37.2	26.5
	950	43	34.7	31.1	.97	37.0	26.5
	980	44	34.0	31.0	.95	37.0	26.5
	1010	45	33.1	29.7	.95	36.5	26.1
	1040	46	33.0	29.7	.92	36.0	25.8
	1070	47	32.3	29.7	.90	36.0	25.6
	1100	48	32.2	29.6	.90	36.0	25.4
	1130	49	31.8	28.9	.85	35.0	25.1
	1160	50	31.8	28.0	.83	34.0	24.8
	1190	51	30.9	28.0	.81	34.0	24.5
	1220	52	30.9	28.0	.80	33.5	24.3

TABLE A-III.- TEST C — DESCENT WATER TANK WITH WATER DISPENSER/  
FIRE EXTINGUISHER, WITH HOKE VALVE - Continued

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Hoke valve press., psid	Water-flow, percent	Hose disch. press., psia
Pretest calibrations			58.0	14.7	0.	0.	14.7
Notes:	1250	53	30.8	28.0	0.80	33.5	24.0
	1280	54	30.1	27.2	.78	33.0	23.8
	1310	55	30.0	27.2	.75	32.5	23.5
	1340	56	29.2	26.6	.73	32.0	23.3
	1370	57	29.2	26.5	.725	32.0	23.0
	1400	58	29.0	26.5	.73	31.5	22.8
	1430	59		26.5	.72	31.2	22.6
	1460	60	29.0	26.0	.71	31.0	22.5
	1490	61		25.9	.70	31.0	22.5
	1520	62		25.9	.70	30.5	22.5
	1550	63	28.0	25.1	.70	30.5	22.4
	1580	64	28.0	25.1	.70	30.0	22.1
	1610	65		25.1	.70	29.5	22.1
	1640	66	27.0	24.5	.70	29.0	22.1
	1670	67		24.3	.70	28.7	21.9
	1700	68		24.0	.70	28.0	21.5
	1730	69		23.8	.67	28.0	21.4
	1760	70	26.0	23.7	.72	28.0	21.3
	1790	71		23.0	.71	28.0	21.0
	1820	72		23.0	.70	27.5	21.0
	1850	73	26.0	23.0	.72	27.0	20.8
	1880	74		22.9	.70	27.0	20.5
	1910	75	25.0	22.9	.70	26.5	20.5
	1940	76		22.9	.69	26.0	20.4
	1970	77		22.9	.72	26.0	20.4
	2000	78	25.0	22.3	.71	26.0	20.3

TABLE A-III.- TEST C — DESCENT WATER TANK WITH WATER DISPENSER/  
FIRE EXTINGUISHER, WITH HOKE VALVE - Continued

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	* Hoke valve press., psid	Water-flow, percent	Hose disch. press., psia
Pretest calibrations			58.0	14.7	0.	0.	14.7
Notes:	2030	79		22.0	0.74	26.5	20.1
	2060	80		22.0	.70	26.0	20.2
	2090	81	24.3	22.0	.70	26.0	20.3
	2150	82	24.0	22.8	.70	26.0	19.9
	2210	84	24.0	22.0	.71	25.5	19.9
	2270	86	24.0	22.0	.70	25.0	19.9
	2330	88	24.0	22.0	.70	24.9	19.6
	2390	90	24.0	22.0	.70	23.5	19.5
	2450	92	23.0	21.3	.70	23.8	19.3
	2510	94	23.0	21.2	.70	23.5	19.2
	2570	96	22.4	21.2	.69	23.5	18.8
	2630	98	22.4	21.2	.69	22.9	18.7
Flow appears adequate	2690	100	21.6	20.6	.70	22.0	18.6
	2750	102	21.6	20.6	.70	22.0	18.4
	2810	104	21.6	20.6	.70	21.0	18.2
	2870	106	21.6	20.6	.73	21.0	18.1
	2930	108	21.6	20.6	.70	20.2	18.0
	2990	110	21.6	20.4	.70	20.0	17.8
	3050	112	20.8	20.4	.68	19.8	17.7
	3110	114	20.8	20.4	.70	19.2	17.6
	3170	116	20.8	20.4	.70	19.0	17.5
	3230	118	20.8	19.9	.71	18.8	17.4
	3290	120	20.8	19.9	.68	18.5	17.4
	3350	122	20.7	19.9	.70	18.2	17.3
	3410	124	20.0	19.2	.70	17.5	17.2
	3470	126	20.0	19.2	.72	17.2	17.1

TABLE A-III.- TEST C — DESCENT WATER TANK WITH WATER DISPENSER/  
FIRE EXTINGUISHER, WITH HOKE VALVE - Continued

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Hoke valve press., psid	Water-flow, percent	Hose disch. press., psia
Pretest calibrations			58.0	14.7	0.	0.	14.7
Erratic readings	3530	128	20.0	19.0	0.69	17.0	17.0
	3590	130	20.0	19.0	.70	16.8	16.8
	3650	132	20.0	19.0	.70	16.2	16.6
	3710	134	20.0	18.6	.69	16.0	16.6
	3770	136	19.5	18.3	.72	15.5	16.5
	3830	138	19.5	18.3	.70	15.0	16.4
Notes:	3890	140	19.5	18.3	.68	15.0	16.3
Erratic flow	3950	142	18.9	18.3	.72	14.5	16.2
	4010	146	18.9	18.3	.71	14.0	16.1
Cone approx 1 to 3 inches diameter at 1 foot away	4070	148	18.9	18.3	.72	13.9	16.0
	4130	150	18.9	18.3	.71	13.8	16.0
	4190	152	18.9	18.3	.70	13.5	15.9
	4250	154	18.9	18.3	.72	12.9	15.8
	4310	156	18.6	18.3	.70	12.2	15.7
	4370	158	18.6	18.3	.70	12.2	15.7
	4430	160	18.6	18.0	.70	12.0	15.6
	4490	162	18.6	18.0	.73	11.5	15.5
	4550	164	18.0	18.0	.72	10.8	15.4
	4610	166	18.0	17.4	.70	10.0	15.3
	4670	168	18.0	17.4	.74	10.0	15.2
	4730	170	18.0	17.4	.66	10.0	15.2
	4790	172	18.0	17.4	.72	9.0	15.1
	4850	174	18.0	17.4	.72	9.0	15.1
	4910	176	18.0	17.4	.70	8.0	15.1
	4970	178	18.0	17.4	.68	8.0	15.0
	5030	180	18.0	17.4	.70	7.0	15.0

TABLE A-III.- TEST C — DESCENT WATER TANK WITH WATER DISPENSER/  
FIRE EXTINGUISHER, WITH HOKE VALVE - Concluded

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Hoke valve press., psid	Water- flow, percent	Hose disch. press., psia
Pretest calibrations			58.0	14.7	0.	0.	14.7
Notes:	5090	182	18.0	17.4	0.70	5.0	15.0
	5150	184	18.0	17.4	.72	5.0	15.0
	5210	186	18.0	17.4	.70	5.0	15.0
	5270	188	18.0	17.4	.78	5.0	14.9
No significant flow	5330	190	18.0	17.4	.07	4.0	14.9
	5390	192	17.9	17.4	.71	3.0	14.8
Test con- cluded							

TABLE A-IV.- TEST D — ASCENT WATER TANK WITH WATER DISPENSER/  
FIRE EXTINGUISHER, WITHOUT HOKE VALVE

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Flow-meter press., psid	Water-flow, percent	Hose disch. press., psia
Pretest calibrations			58.0	14.7	0.	0.	14.7
Notes:	5	1	50.5	46.3	0.32	54.0	40.0
7/19/68	10	2	47.0	43.7	.30	51.0	38.2
Start	15	3	44.0	40.8	.29	49.0	36.2
2:03 pm	20	4	41.0	38.4	.28	46.0	33.2
Stop	2:13 pm	5	39.0	37.0	.28	44.0	32.0
Cone of spray approx 4 to 6 feet diameter at 6 feet away	40	6	37.2	34.9	.27	42.0	30.7
	50	7	36.0	34.0	.27	41.0	29.8
	60	8	34.9	32.8	.27	40.0	29.0
	70	9	34.0	32.0	.27	39.0	28.3
	80	10	33.4	31.9	.26	38.0	27.8
	90	11	32.1	29.9	.26	37.0	27.0
	100	12	31.2	29.8	.26	36.0	26.2
	110	13	30.6	29.0	.25	35.0	25.7
	120	14	29.8	28.2	.25	34.0	24.9
	130	15	29.0	26.9	.25	33.0	24.5
	140	16	28.0	26.9	.25	32.0	24.0
	150	17	27.8	26.1	.25	32.0	23.7
	160	18	27.2	25.3	.24	31.0	23.3
	170	19	26.7	25.2	.25	30.5	23.0
	180	20	26.3	24.9	.25	30.0	22.7
	190	21	25.9	24.0	.25	29.5	22.3
	200	22	25.7	24.0	.25	29.0	21.9
	210	23	25.1	23.2	.24	28.0	21.6
	220	24	24.8	23.2	.25	27.0	21.6
	230	25	24.2	23.2	.25	27.0	21.1
	240	26	24.1	23.2	.25	26.5	20.9

TABLE A-IV.- TEST D — ASCENT WATER TANK WITH WATER DISPENSER/  
FIRE EXTINGUISHER, WITHOUT HOKE VALVE - Continued

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Flow-meter press., psid	Water-flow, percent	Hose disch. press., psia
Pretest calibrations			58.0	14.7	0.	0.	14.7
Notes:	250	27	23.8	22.3	0.25	26.0	20.8
	260	28	23.7	21.8	.25	26.0	20.6
	270	29	23.3	21.8	.25	25.0	20.3
	280	30	23.2	21.8	.25	24.0	20.1
	290	31	22.8	21.0	.25	23.5	19.9
	300	32	22.4	21.0	.26	23.5	19.5
	310	33	22.0	21.0	.25	23.0	19.3
	320	34	21.9	21.0	.25	22.0	19.0
	330	35	21.4	20.2	.26	22.0	18.9
	340	36	21.4	20.2	.24	20.0	18.7
Erratic flow cone spray approx 2 to 3 inches diameter at 1 foot away	350	37	21.0	20.2	.26	21.5	18.5
	360	38	21.0	19.5	.25	20.0	18.4
	370	39	20.6	19.5	.25	26.0	18.2
	380	40	20.5	19.5	.26	19.5	18.1
	390	41	20.5	19.5	.26	19.0	17.9
	400	42	20.2	19.5	.26	19.0	17.8
	410	43	20.1	19.5	.24	18.0	17.6
	420	44	20.1	19.5	.26	17.5	17.6
	430	45	19.6	19.5	.26	17.0	17.5
	440	46	19.6	19.5	.26	17.0	17.4
	450	47	19.6	18.9	.26	17.0	17.3
	460	48	19.0	18.9	.26	16.0	17.2
	470	49	19.0	18.2	.26	16.0	17.0
	480	50	19.0	18.2	.26	15.0	16.9
	490	51	19.0	18.2	.26	15.0	16.8
	500	52	18.9	18.2	.26	14.0	16.7

TABLE A-IV.- TEST D -- ASCENT WATER TANK WITH WATER DISPENSER/  
FIRE EXTINGUISHER, WITHOUT HOKE VALVE - Concluded

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Flow- meter press., psid	Water- flow, percent	Hose disch. press., psia
Pretest calibrations			58.0	14.7	0.	0.	14.7
Notes:	510	53	18.9	18.2	.26	13.5	16.6
	520	54	18.8	18.2	.26	13.0	16.5
	530	55	18.8	17.5	.26	12.0	16.4
	540	56	18.8	17.5	.25	12.0	16.3
	550	57	18.8	17.5	.25	12.0	16.2
	560	58	18.3	17.5	.25	11.0	16.1
No significant flow	570	59	18.3	17.5	.24	10.5	15.9
	580	60	18.2	17.5	.25	10.0	15.8
Test con- cluded							

TABLE A-V.- TEST E — DESCENT WATER TANK WITH WATER DISPENSER/  
FIRE EXTINGUISHER, WITHOUT HOSE VALVE

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Flow-meter press., psid	Water-flow, percent	Hose disch. press., psia
Pretest calibrations			58.0	57.7	0.	0.	14.7
Notes:	5	1	57.9	51.7		58.0	45.0
7/29/68	10	2	57.0	51.0		57.0	43.5
Start 2:02 pm	15	3	57.0	50.7		57.0	43.0
Stop 3:25 pm	20	4	56.2	50.1		56.0	42.9
	25	5	56.0	50.0		56.0	42.5
Spray cone approx 4 to 6 feet diameter at 6 feet away	30	6	55.3	49.5		56.0	42.3
	35	7	55.1	49.2		56.0	42.0
	40	8	55.1	49.1		56.0	41.9
	45	9	54.7	49.1		56.0	41.7
	50	10	54.6	49.0		56.0	41.5
	65	11	53.9	48.4		55.5	41.3
	80	12	53.8	47.8		55.0	40.8
	95	13	53.0	47.8		55.0	40.5
	110	14	52.1	47.0	0.35	54.5	40.0
	125	15	52.1	46.9		54.0	39.6
	140	16	51.3	46.3	.33	54.0	39.4
	170	17	51.3	46.2		53.8	39.2
	200	18	49.8	45.0	.33	52.5	38.3
	230	19	49.0	44.1		52.0	37.6
	260	20	48.1	43.5	.31	51.2	37.0
	290	21	47.3	43.0		50.5	36.5
	320	22	47.0	42.8	.30	50.2	36.2
	350	23	46.4	42.0		49.0	35.8
	380	24	45.7	41.3	.30	49.0	35.2
	410	25	45.0	40.9		48.5	34.6
	440	26	44.0	40.3	.29	48.0	34.2

TABLE A-V.- TEST E — DESCENT WATER TANK WITH WATER DISPENSER/  
FIRE EXTINGUISHER, WITHOUT HOKE VALVE - Continued

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Flow- meter press., psid	Water- flow, percent	Hose disch. press., psia
Pretest calibrations			58.0	57.7	0.	0.	14.7
Notes:	470	27	43.9	39.9		47.0	33.8
	500	28	43.4	39.1	0.28	46.5	33.2
	530	29	42.2	38.6		46.0	33.0
	560	30	42.1	38.4	.27	45.5	32.6
	590	31	41.4	37.0		45.0	32.2
	620	32	40.9	37.0	.26	44.5	32.0
	650	33	40.7	36.6		44.0	31.5
	680	34	39.9	36.3	.26	44.0	31.2
	710	35	39.0	36.1		43.5	30.8
	740	36	38.2	35.5	.26	42.5	30.2
	770	37	37.7	34.9		42.0	29.9
	810	38	37.3	34.0	.26	41.5	29.5
	840	39	37.0	34.0	.26	41.0	29.2
	870	40	36.7	33.3		41.0	28.9
	900	41	36.0	33.3	.26	40.5	28.7
	930	42	36.0	32.9	.25	40.0	28.5
	960	43	35.0	32.0	.25	39.5	28.0
	990	44	35.0	32.0		39.5	27.8
	1020	45	34.3	32.0	.25	39.0	27.7
	1050	46	34.2	31.1		39.0	27.5
	1080	47	33.7	31.1	.25	38.5	27.2
	1110	48	33.7	30.7		38.5	27.0
	1140	49	33.0	30.7	.25	38.0	26.7
	1170	50	32.9	29.9		37.5	26.5
	1230	51	32.0	29.0	.25	37.0	26.0
	1290	52	31.9	29.0		36.5	25.7

TABLE A-V.- TEST E — DESCENT WATER TANK WITH WATER DISPENSER/  
FIRE EXTINGUISHER, WITHOUT HOKE VALVE - Continued

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Flow- meter press., psid	Water- flow, percent	Hose disch. press., psia
Pretest calibrations			58.0	57.7	0.	0.	14.7
Notes:	1350	53	31.1	28.1	0.25	36.0	25.4
	1410	54	30.3	28.1		35.5	25.0
	1470	55	30.2	27.3	.24	35.0	24.7
	1530	56	29.7	26.8		34.5	24.4
	1590	57	29.4	26.8	.23	34.0	24.1
	1650	58	28.6	26.0	.23	33.5	23.5
	1710	59				33.0	23.3
	1770	60	27.9	25.2	.23	32.0	22.9
	1830	61				31.5	22.7
	1890	62	27.0	24.6	.22	31.0	22.5
	1950	63				30.5	22.3
	2010	64				30.0	22.0
	2070	65	26.2	23.8	.21	29.5	21.7
	2130	66				29.0	21.6
	2190	67				29.0	21.4
	2250	68	25.0	23.0	.21	28.5	21.2
	2310	69				28.0	21.0
	2370	70	24.9	22.4	.20	27.5	21.0
	2430	71				27.0	20.8
	2490	72				27.0	20.6
	2550	73	24.0	22.2	.21	27.0	20.5
	2610	74				26.5	20.3
	2670	75				26.0	20.2
	2730	76	23.9	21.8	.21	25.5	20.0
	2790	77	23.0	21.6	.21	25.0	19.8
	2850	78				25.0	19.7

TABLE A-V.- TEST E -- DESCENT WATER TANK WITH WATER DISPENSER/  
FIRE EXTINGUISHER, WITHOUT HOKE VALVE - Continued

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Flow- meter press., psid	Water- flow, percent	Hose disch. press., psia
Pretest calibrations			58.0	57.7	0.	0.	14.7
Notes:	2910	79	23.0	21.4	.21	24.5	19.5
	2970	80				24.0	19.5
Somewhat erratic readings	3030	81	22.4	20.7	.21	24.0	19.3
	3090	82				23.5	19.1
	3150	83	21.7	20.7	.20	23.5	19.0
	3210	84				23.5	18.8
	3270	85	21.7	20.0	.21	22.5	18.8
	3330	86				22.5	18.7
	3390	87	21.7	20.0	.20	22.0	18.5
	3450	88				22.0	18.5
	3510	89	20.9	20.0	.21	21.5	18.4
	3570	90				21.0	18.2
	3630	91	20.9	20.0	.21	20.5	18.2
	3690	92				20.0	18.0
	3750	93				19.5	18.0
	3810	94	20.8	19.2	.20	19.5	17.9
	3870	95				19.0	17.7
	3930	96	19.9	19.1	.21	19.0	17.6
	3990	97	19.9	19.1		18.5	17.5
	4050	98			.21	18.0	17.4
	4110	99	19.9	19.1		17.5	17.4
	4170	100	19.9		.20	17.5	17.3
	4230	101	19.8	19.1		17.0	17.2
Erratic flow	4290	102				17.0	17.1
	4350	103	19.8	19.1	.20	16.5	17.0

TABLE A-V.- TEST E — DESCENT WATER TANK WITH WATER DISPENSER/  
FIRE EXTINGUISHER, WITHOUT HOKE VALVE - Concluded

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Flow-meter press., psid	Water-flow, percent	Hose disch. press., psia
Pretest calibrations			58.0	57.0	0.	0.	14.7
Cone spray approx 2 to 3 inches diameter at 1 foot away	4410 4470 4530 4590 4650 4710 4770 4830 4890 4950	104 105 106 107 108 109 110 111 112 113	19.0 19.0 19.0 19.0 18.2 18.2 18.2 18.2	18.5 18.5 18.5 18.5 18.3 18.3 18.3 18.3	0.20 .21 .20 .20	16.0 16.0 16.0 15.0 15.0 14.0 14.0 14.0 13.5 13.0	16.9 16.8 16.8 16.7 16.5 16.5 16.4 16.3 16.2 16.2
Flow not adequate	5010	114					
Test concluded							

TABLE A-VI.- TEST F — ASCENT WATER TANK WITH WATER DISPENSER/  
FIRE EXTINGUISHER, WITHOUT HOKE VALVE

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Flow-meter press., psid	Water-flow, percent	Hose disch. press., psia
Pretest calibrations			59.0	56.2	0.	0.	14.7
Notes:	10	1	53.2	49.2	0.33	56.0	42.0
7/29/68	20	2	49.8	46.7	.33	54.0	39.7
Start 11:45 am	30	3	48.0	44.2	.31	52.0	38.0
Stop 12:02 pm	40	4	46.8	42.8	.31	51.0	36.8
	50	5	45.5	42.0	.31	50.0	35.8
Spray cone approx 5 to 6 feet diameter at 6 feet away	60	6	44.0	40.6	.31	49.0	35.0
	70	7	42.7	39.2	.30	47.0	34.0
	80	8	41.4	38.3	.30	46.0	33.3
	90	9	40.4	37.6	.29	45.0	32.5
	100	10	39.0	36.9	.29	44.0	31.4
	110	11	38.0	35.5	.28	43.5	30.5
	120	12	37. <sup>1</sup>	34.8	.28	43.0	29.9
	130	13	36.8	34.0	.26	42.0	29.2
	140	14	36.0	33.4	.26	41.0	28.7
	150	15	35.3	33.0	.27	40.0	28.2
	160	16	35.0	32.5	.27	39.0	27.7
	170	17	34.0	31.8	.26	38.0	27.4
	180	18	33.3	31.1	.26	37.0	26.7
	190	19	32.0	28.8	.26	36.0	25.7
	200	20	31.0	28.8	.25	36.0	25.5
	210	21	30.0	28.0	.25	35.0	25.0
	220	22	30.0	28.0	.25	34.0	24.5
	230	23	29.0	27.3	.25	32.0	24.3
	240	24	28.5	27.3	.25	32.0	23.7
	250	25	28.0	26.9	.25	32.0	23.5
	260	26	28.0	26.6	.25	31.0	23.2

TABLE A-VI.- TEST F — ASCENT WATER TANK WITH WATER DISPENSER/  
FIRE EXTINGUISHER, WITHOUT HOKE VALVE - Continued

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Flow- meter press., psid	Water- flow, percent	Hcse disch. press., psia
Pretest calibrations			59.0	56.2	0.	0.	14.7
Notes:	270	27	27.7	25.2	.25	31.0	23.0
	280	28	27.2	25.2	.25	30.0	22.7
	290	29	27.0	25.2	.25	30.0	22.5
	300	30	27.0	24.4	.25	29.0	22.3
	310	31	26.2	24.4	.25	29.0	22.0
	320	32	26.0	24.4	.25	29.0	21.7
	330	33	26.0	23.8	.25	28.0	21.3
	340	34	25.5	23.8	.25	28.0	21.2
	350	35	25.0	23.8	.25	27.0	20.9
	360	36	25.0	23.0	.24	27.0	20.8
	370	37	24.9	23.0	.24	27.0	20.7
	380	38	24.7	23.0	.24	27.0	20.6
	390	39	24.3	23.0	.24	26.0	20.4
Adequate flow	400	40	24.0	22.3	.24	26.0	20.0
	420	41	23.8	21.5	.22	25.0	19.8
	440	42	23.4	21.5	.22	25.0	19.6
	460	43	23.1	21.5	.23	25.0	19.3
	480	44	22.8	21.5	.23	23.0	18.9
	500	45	22.5	20.9	.23	23.0	18.8
	520	46	22.0	20.2	.23	22.0	18.5
	540	47	21.6	20.0	.23	22.0	18.4
	560	48	21.5	20.0	.22	22.0	18.2
Erratic flow	580	49	21.5	20.0	.22	21.0	18.0
2 to 3 inches diameter cone at 1 foot away	600	50	21.0	20.0	.23	20.0	17.9
	620	51	21.0	20.0	.23	20.0	17.7
	640	52	20.7	20.0	.23	19.0	17.5

TABLE A-VI.- TEST F — ASCENT WATER TANK WITH WATER DISPENSER/  
FIRE EXTINGUISHER, WITHOUT HOKE VALVE - Concluded

Measurements	Time elapsed, sec	Data point	Descent tank press., psia	Discon. disch. press., psia	Flow-meter press., psid	Water-flow, percent	Hose disch. press., psia
Pretest calibrations			59.0	56.2	0.	0.	14.7
Notes:	660	53	20.4	20.0	.23	19.0	17.4
	680	54	20.2	19.3	.23	18.0	17.2
	700	55	20.0	19.3	.23	17.0	17.1
	720	56	20.0	19.3	.23	17.0	17.0
	740	57	19.9	19.3	.23	16.0	16.8
	760	58	19.7	18.8	.23	16.0	16.7
	780	59	19.6	18.8	.23	16.0	17.7
	800	60	19.5	18.8	.22	15.0	17.5
	820	61	19.0	18.7	.22	14.0	16.4
	840	62	19.0	18.7	.23	14.0	16.3
	860	63	19.0	18.6	.23	14.0	16.3
	880	64	18.8	18.6	.23	13.0	16.2
	990	65	18.8	18.6	.23	12.0	15.9
	920	66	18.8	18.6	.23	12.0	15.8
	940	67	18.8	18.6	.23	12.0	15.7
	960	68	18.8	18.0	.20	11.0	15.6
	980	69	18.5	18.0	.20	11.0	15.6
	1000	70	18.3	17.9	.21	11.0	15.5
	1020	71	18.3	17.9	.21	10.0	15.4
No significant flow	1040	72	18.2	17.9	.21	9.0	15.3
Test concluded							

## APPENDIX B

METHOD TO DETERMINE QUANTITY OF WATER LEFT IN THE TANKS AT  
ANY GIVEN PRESSURE

## APPENDIX B

METHOD TO DETERMINE QUANTITY OF WATER LEFT IN THE TANKS  
 AT ANY GIVEN PRESSURE

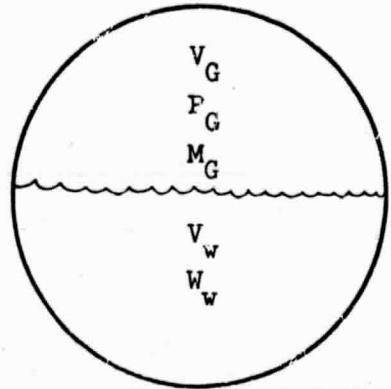
Determination of the water left in the tanks at any given pressure was obtained in the following typical manner.

Volume of gas:

$$V_G = \frac{M_G RT_G}{P_G}$$

Volume of water:

$$V_w = V - \frac{M_G RT_G}{P_G}$$



Weight of water:

$$W_w = \left( V - \frac{M_G RT_G}{P_G} \right) 62.4$$

Where  $V$  = total volume

$V_w$  = volume of water

$M$  = mass

$W_w$  = weight of water

$T$  = temperature

$R$  = universal gas constant

62.4 = density of water

$G = \text{gas}$

$P = \text{pressure}$

$$M_G = \text{constant} = \text{initial mass of gas} = M_{G_i}$$

$$M_{G_i} = \frac{P_i V_i}{R T_i} \quad \text{for } N_2 \quad R = 55.2 \frac{\text{lb-ft}}{\text{lb}^{\circ}\text{R}}$$

$$T = 70^{\circ} \text{ F} = 530^{\circ} \text{ R}$$

$$V_i = 0.2 V_T \text{ ft}^3$$

$$P_i = 58 \text{ psia}$$

$$V_T \text{ (descent tank)} = 7.14 \text{ ft}^3$$

$$V_T \text{ (ascent tank)} = 0.91 \text{ ft}^3$$

Water capability:

Descent tank — 446 lb

Ascent tank — 56.8 lb

Total — 502.8  $\approx$  503 lb

Total water loaded in tanks:

Descent tank — 357 lb

Ascent tank — 46 lb

Total — 403 lb

Therefore,

$$\text{Fill ratio } \frac{403}{503} = 0.803 \text{ for water}$$

$$1 - 0.803 = 0.197 \text{ for gas, } \approx 0.2$$

Descent tank:

$$M_{G_i} = \frac{P_i V_i}{RT_i} = \frac{28(0.2)(7.14)(144)}{(55.2)(530)}$$

$$M_{G_i} = 0.408 \text{ lb}$$

$$V_G = \frac{M_{G_i} RT_G}{P_G} = \frac{0.408(55.2)(530)}{144 F_G} = \text{ft}^3$$

$$V_G = \frac{83}{P} \text{ ft}^3$$

Therefore, water left in tank (lb)

$$w_w = \left( 7.14 - \frac{83}{P} \right) 62.4 \quad (1)$$

By substituting  $P$  in equation (1) by the desired pressure, the weight of the water left in the tank can be obtained. To obtain the weight of the water used, merely subtract the value obtained in equation (1) from the weight of water loaded in the tank.

Similarly, the following equation will furnish the weight of water left in the ascent tank:

$$w_w = \left( 0.91 - \frac{10.6}{P} \right) 62.4 \quad (2)$$

## APPENDIX C

### TEST PROCEDURES

The procedures contained in Appendix C are excerpts from Structures Branch Report 68-ES4-2 entitled Development Test Plan for LM Water Management System for Fire Extinguishing Purposes.

## TEST PROCEDURE

Step Description

- 1 Fill water management simulator, using water fill procedure given in Attachment.
- 2 Measure differential pressure across descent water tank and hose assembly (see fig. C-2).
- 3 Calibration of reference point:
  - a. Record pressure at descent tank instrument port (item 1).
  - b. Record pressure of item 3.
  - c. Record differential pressure of item 4.
  - d. Record flow of flowmeter (0 flow will establish reference point).
  - e. Record pressure of pressure transducer at outlet end of hose without the water dispenser/fire extinguisher (item 7).
- 4 Measurement of parameters at flow conditions
  - a. Slowly open SOV 1 on the WMS until the reading on item 3 stabilizes.
  - b. Slowly open the Hoke valve on the hose and consecutively establish the following flows:
    - (1) 0.5 lb/min
    - (2) 0.85 lb/min
    - (3) 1.0 lb/min
    - (4) 2.0 lb/min
    - (5) 3.0 lb/min
    - (6) 4.0 lb/min
    - (7) 5.0 lb/min
    - (8) 6.0 lb/min
    - (9) 7.0 lb/min
    - (10) 8.0 lb/min
    - (11) 9.0 lb/min
    - (12) 10.0 lb/min

- c. At each of the above flows, record the following:
    - (1) Descent tank pressure (item 1)
    - (2) Disconnect discharge pressure (item 3)
    - (3) Valve differential pressure (item 4)
    - (4) Hose discharge pressure (pressure transducer)
  - d. Follow steps b and c, starting with a 10 lb/min flow and decreasing to 0.5 lb/min.
  - e. Continue steps b, c, and d until the descent tank is empty.
  - f. Close SOV 1 and the Hoke valve.
- 5 Measure differential pressure across ascent water tank and hose assembly (see fig. C-2).
  - 6 Calibration of reference point (follow step 3, using item 2 in place of item 1 on the WMS).
  - 7 Measurement of parameters at flow conditions (follow step 4, using item 2 and SOV 2 in place of item 1 and SOV 1 on the WMS).
  - 8 Close SOV 2 and the Hoke valve.
  - 9 Fill water management simulator, using water fill procedure given in Attachment.
  - 10 Measure differential pressure across descent water tank and hose assembly (see fig. C-2).
  - 11 Calibration of reference point:
    - a. Record pressure at descent tank instrument port (item 1).
    - b. Record pressure of item 3.
    - c. Record differential pressure of item 4 (0  $\Delta P$  will establish reference point).
    - d. Record flow of flowmeter (0 flow will establish reference point).
    - e. Record pressure of pressure transducer at outlet end of hose upstream of water dispenser/fire extinguisher (item 7).

## 12 Measurement of parameters at flow conditions:

- a. Slowly open SOV 1 on the WMS until the reading on item 3 stabilizes.
- b. Slowly open the Hoke valve and maintain 0.7 psia  $\Delta P$  on item 4.
- c. As tank pressure decreases and while maintaining 0.7 psia  $\Delta P$  across item 4, record the following:
  - (1) Descent water tank pressure (item 1).
  - (2) Disconnect discharge pressure (item 3).
  - (3) Flow rate (item 5).
  - (4) Hose discharge pressure (item 6).
- d. Continue step c until the descent water tank is empty.
- e. Close SOV 1 and the Hoke valve.

13 Remove Hoke valve (item 4) from the system.

14 Calibration of reference point (follow step 11 except for use of ascent tank in step a and deletion of step c).

15 Measurement of parameters at flow conditions (follow step 12) using the ascent tank (item 2) and SOV 2 in place of item 1 and SOV 1 on the WMS.

NOTE: Since the Hoke valve has been removed from the system, there will not be  $\Delta P$  recordings.

16 At completion of test, remove the hose assembly and cap all openings and fittings.

## ATTACHMENT

Fill Procedure

1

The configuration of the water transfer unit (WTU) shall be as follows (see fig. C-3):

- a. All valves are closed and the gas system has been vented.
- b. The GN<sub>2</sub> supply is connected to the MD1 fitting.
- c. The water supply line (LDW 430-54379-9) is connected to MD5.

2

The configuration of the WMS shall be as follows (see figs. C-1 and C-2):

- a. SOV 1 and SOV 2 shall be closed.
- b. The Hoke valve on the hose assembly shall be closed.

3

The configuration of the water servicing manifold (WSM) shall be as follows (see fig. C-3):

- a. The water supply hose (LDW 430-54379-9) shall be affixed to the SOV 2 fitting.
- b. One water supply line (LDW 430-54379-3) and both GN<sub>2</sub> supply lines (LDW 430-54379-1) shall be connected to the WMS.
- c. SOV 1 through 12 shall be closed.
- d. The GN<sub>2</sub> supply line shall be connected to the "T" on the SOV 3 fitting.

4

WTU:

- a. Open V<sub>1</sub> and V<sub>5</sub> and set G<sub>1</sub> to read 3<sup>4</sup> psig by adjusting PR<sub>2</sub>.
- b. Open V<sub>10</sub> and V<sub>11</sub>.

5           WMS: Open SOV 1 and SOV 2.

6           WSM:

- a. Open SOV 4, 6, 7, 8.
- b. Start the vacuum pump and open SOV 3.
- c. Pull down system to 2.0 mm Hg as read out at vacuum pump.
- d. Close SOV 4, 6 and bleed in  $\text{GN}_2$  to 11.9 psia.

7           WTU:

- a. Record flowmeter reading.
- b. Open  $V_{15}$ .

8           WSM: Open SOV 2, 6.

- 9
- a. Let system fill until flowmeter on WTU stops indicating flow (maintain a  $\frac{3}{4}$  psig blanket  $\text{GN}_2$  pressure).
  - b. Close all valves on WSM.
  - c. Record flowmeter reading on WTU.
  - d. Close SOV 1 and SOV 2 on the WMS.
  - e. Remove all lines from the WMS and cap disconnects.

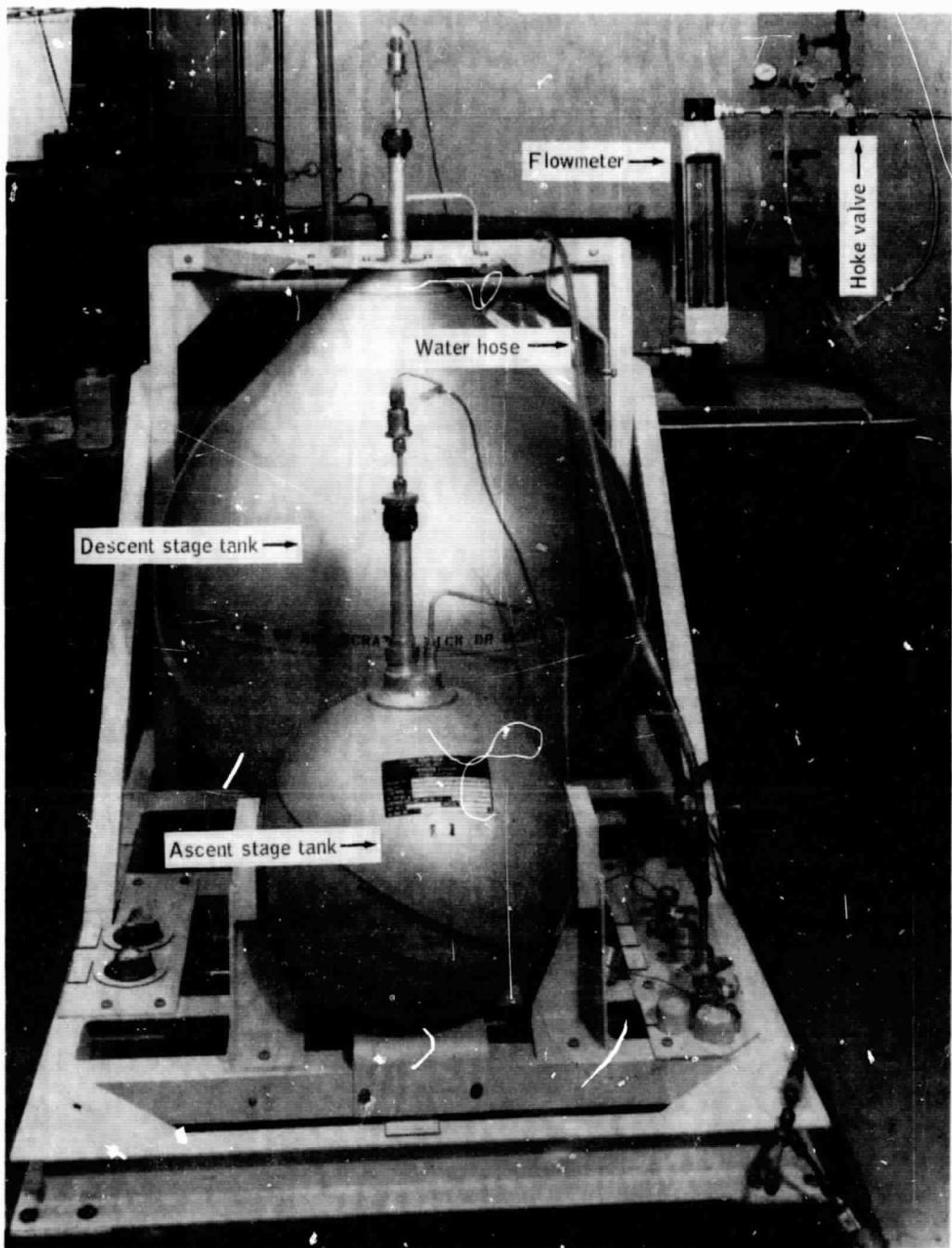


Figure C-1.- The LM Water Management System simulator.

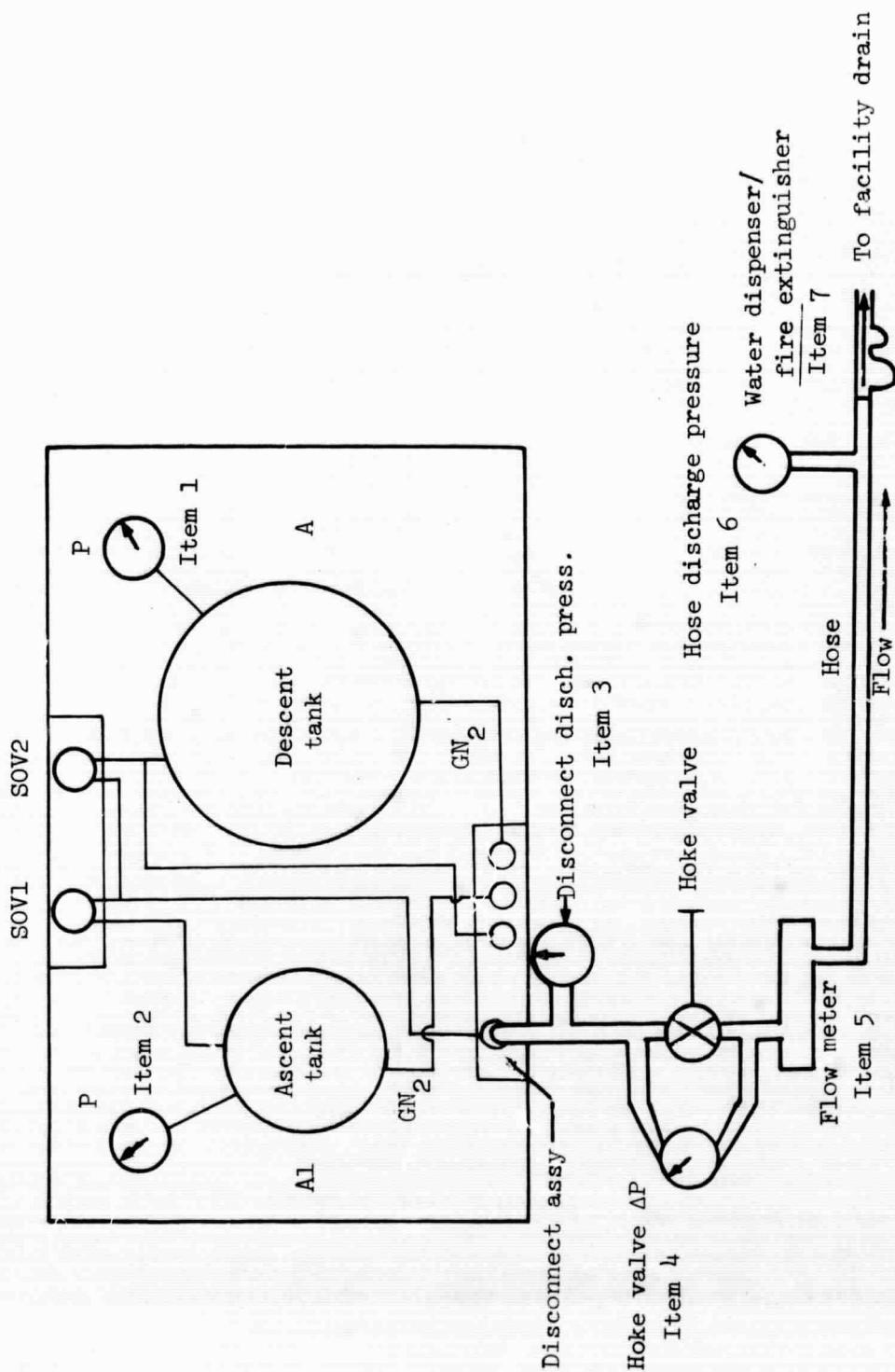


Figure C-2.- Schematic diagram of LM Water Management System simulator.

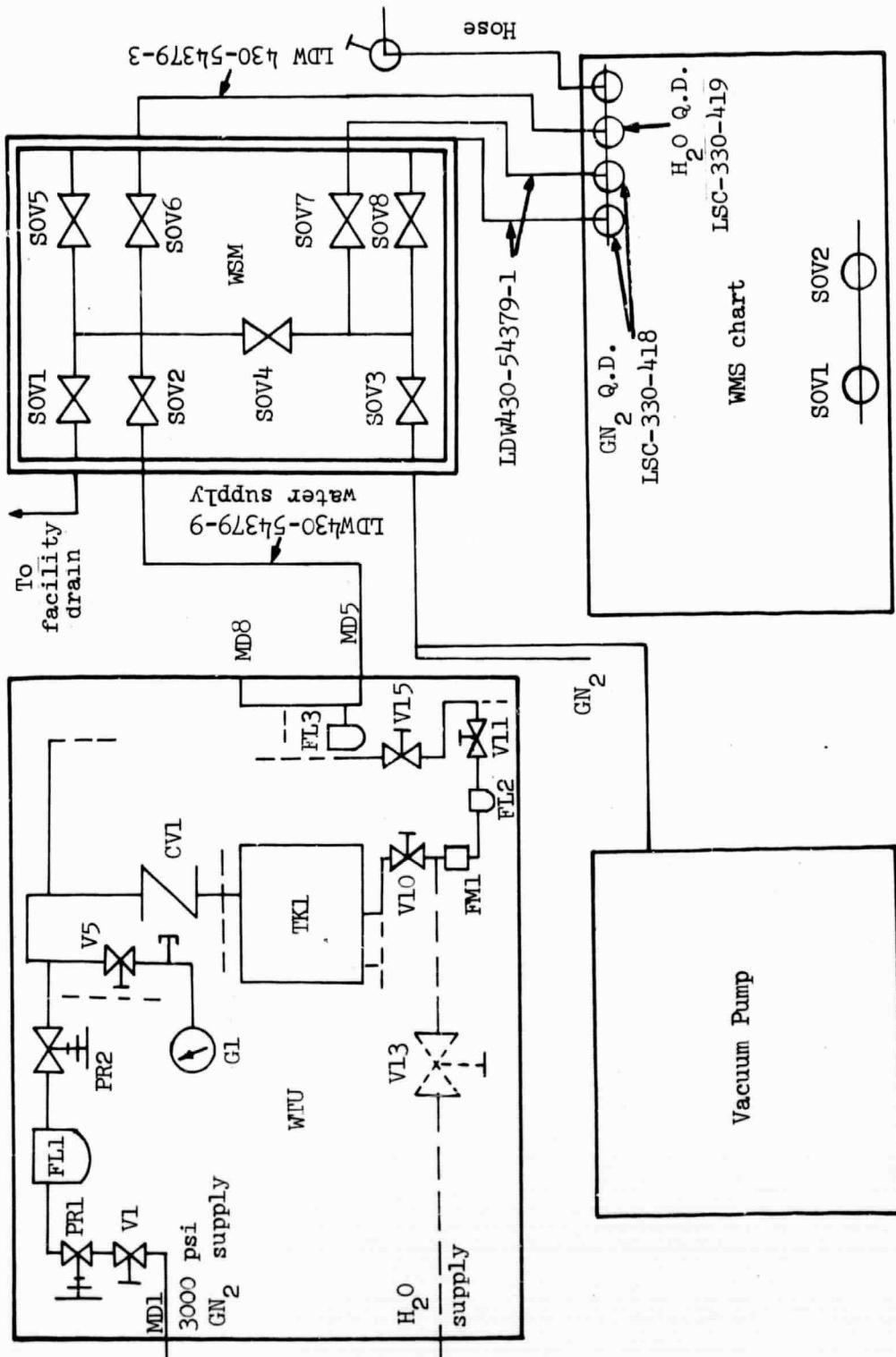


Figure C-3 . - Schematic diagram of Water Management System charging unit.